PROTECTIVE IRRIGATION WORKS,

RAJPUTANA.

REPORT

ON THE

BANAS CANAL PROJECT,

WITH

NOTE BY THE CONSULTING ENGINEER FOR IRRIGATION IN RAJPUTANA.

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BANAS CANAL PROJECT.

NOTE BY THE CONSULTING ENGINEER FOR IRRIGATION IN RAJPUTANA.

Note by Col. Sir Swinton Jacob, K.C.I.E., Consulting Engineer for Irrigation, on the Report on the Banas Canal Project, prepared under the Supervision of Mr. F. St.-G. Manners Smith, Superintending Engineer, Protective Irrigation Works.

In Rajputana there are many nullahs which flow in the rains only; advantage has been taken here and there to store some of the flood water of a few of them for Irrigation, but no attempt has been made hitherto to deal with the immense amount of water which goes to waste in some of the largest rivers, partly perhaps because of political difficulties, as the large rivers generally flow through two or more Native States, and partly, no doubt, for want of data, and because it is beyond the powers of the Native States now to deal with works of any magnitude; although there are grand works existing in Mewar, for example, showing that where there is the will and unlimited funds, how much may be done.

2. On the recommendation of the Irrigation Commission, the Government of India, with the consent of the Native States, promptly sanctioned the proposal to investigate the possibilities of Irrigation in Rajputana. And the officers entrusted with this duty naturally turned to see if anything could be done with the Banas, the largest river in Rajputana. This has been carefully examined, and a site, where it was thought a good Storage Reservoir might be made, was inspected and approved by the Consulting Engineer in March 1903.

3. The Surveys and Plans and Estimates have since been prepared under the supervision of Mr. Manners Smith, and are submitted with his Report.

4. Perhaps objections may be made that this Project is too large, but no Irrigation Project can be considered thoroughly satisfactory which does not provide a Storage Reservoir which shall have a supply of water sufficient to meet the requirements of bad years, and it would have been a matter of regret if the opportunity had not been taken of showing how it is possible to deal with a large river like the Banas, and even in Rajputana to make one of the finest Storage Reservoirs in India.

5. The unintercepted Catchment Area at Amarpura, the site of the proposed Dam, is 5,600 sq. miles (*para. 8*). The capacity of the proposed lake is 15,077 m. c. ft., and with a run-off of only $\frac{1}{20}$th of a 24″ rainfall, the Reservoir ought to fill and overflow.

The river at the site of the Dam is only 720 ft. wide, with rock on both banks. When the lake is full the water will spread over an area of about 30 sq. miles, most of it waste land; and allowing 100,000 c. ft. per acre, inclusive of absorption and evaporation, there would be water sufficient to irrigate 156,767 acres, or 245 sq. miles (*para. 16*).

6. The depth of water, 80 ft., cannot be increased (above R. L. 585), without damaging large villages like Chaprel, Nandrai, and Bigod, and even at this level 37 hamlets will be submerged, wholly or in part. Compensation has been taken in the Estimate for this. No account has been taken of the increased cultivation which ought to take place round the margin, as the water recedes.

7. The cost of the work is as under :—

Dam	Rs.	23,58,189
High-level Canal ...	„	6,02,457
Low-level Canal	„	10,00,000
Compensation for 37 hamlets	„	1,11,000
Total	Rs.	40,71,646

8. Mr. Manners Smith's Report shows how carefully all the Engineering features have been considered; the foundations tested; the stability of the Dam determined; how the flood discharges have been arrived at and provided for, and the Irrigation Canals laid out; and how the Plans and Estimates for all have been prepared.

9. I have inspected the site, and the Plans and the Estimates. I approve of all, and wish only to add the following remarks :—

Regarding the Project from an Engineering point of view only, I think the Superintending Engineer is on the safe side in arranging for the flood discharges. He has allowed for the Reservoir to be full up to R. L. 572, and then allows the highest known flood, 352,672 c. ft. per second to continue for 63½ hours, and shows that this immense quantity of water can be safely dealt with, though he considers that it is impossible for a flood of this magnitude to continue for more than 24 hours. It seems also to me very improbable that such floods will ever continue so long; still in India, especially with floods in large rivers, one can never be sure that the improbable may not occur, and I do not feel disposed to take the responsibility of saying it is impossible, though I do think it is highly improbable.

10. Regarding the Project from a financial point of view, I am disposed to think some modification may be made.

Suppose that the masonry Dam is built, in the river portion only, up to the full height R. L. 593. This is advisable, I think, so that the Under-sluices and the arrangement for working them shall be properly carried out once for all. But I think it might be advisable to omit the automatic gates for the present, and to build the masonry of this portion only up to R. L. 572, the sill of these automatic gates, so that they can be put in whenever required.

11. The effect of th's would be as follows :—

As regards the quantity of water: the water will only be stored up to sill level of the automatic gates, R. L. 572 instead of R. L. 580, and will spread over an area of about 20 sq. miles instead of 30. The quantity stored would be 10,359 m. c. ft. instead of 15,676. The amount available for Irrigation would be half the quantity between 572 and the sill of the Sluice at 550, *viz.*, $\frac{7345}{2}$ m. c.ft. = 3,672 m. c.ft., sufficient for 36,720 acres, or 57 sq. miles of irrigated land. Considering the nature of the country and the sparse population, it would probably be some years before all this land was fully irrigated.

When it was found by experience more water was required, it would be very easy to put up the automatic gates and increase the storage to 15,676 m. c. ft.

12. As regards the financial aspect, this would effect a saving on the original outlay as follows :—

Cost of the automatic gates	Rs.	4,72,500
Contingencies on the above	,,	23,625
Total ...	Rs.	4,96,125

inculding masonry say 5 lakhs ; the interest on this sum would be an annual saving of about Rs. 25,000, and until all the water stored up to R. L. 572 is used, it is evident that this would be a charge which need not be incurred, and would only increase the liability to be annually recovered.

13. It will be observed that there is nothing in the above proposal which interferes with the completion of the work up to the full level whenever it is desired, for it is hoped, eventually, when the value of the water is appreciated and cultivators are found to take up all the land, that the work will be carried up to the full height. In the meantime the Estimate has been taken out to show what the total cost will be. When the work has proved a success, the people themselves will no doubt be only too glad to spend the extra amount to complete it fully.

14. The Left Canal has been designed to give a watering of 6 inches within 30 days to all land that can be irrigated. This is an important point, for it is no use to offer cultivators water when the time for the first watering is past. It is believed this is the reason why sometimes Irrigation works have not been a success, when they otherwise would have been ; the water has been there, and the land has been waiting for the water, but it has not reached the land in time to be of use.

15. Although the sill of the outlet Sluice for the Left Canal is fixed at R. L. 550, and 30 ft. of water remains below it in the reservoir, this water is not lost : it is all available for letting down the river until it can be used for the Canal which it is proposed to take off, at a suitable place, lower down.

Regarding the Canal on the right bank—As a Project for this was prepared some years ago by the Jaipur State, and it was known to be feasible, in order to save time and money, the amount of that Estimate has been accepted and included in the present Project, although when this Project is sanctioned, detailed Surveys for the right bank Canal will have to be made.

16. I would now suggest the Government of India be asked to send some special officer, as soon as possible, to report upon the Project; to satisfy themselves that the Project is really a sound one, and that it can be carried out for the sum named.

17. Supposing the Project has been pronounced a sound one. This brings us to the second stage—when and how the work is to be carried out. Is it to be left to a year of famine? The object of the work is to protect as large an area as possible from famine; if the Project is a sound one, to hesitate about it, until famine is approaching would be a fatal policy.

How will it be possible to start a large work of this kind properly when famine is approaching? The difficulty of providing suddenly for an influx of half-starved people would be almost impossible, excepting on the Canal portion. The Dam requires skilled labour, especially in the foundations. The Sluices would require to be ordered months beforehand.

18. Every year that the work is delayed one sees millions of tons of water flowing away to the sea, while the country is parched up for want of water. If the Project is a sound one, can money be put to a better use?

For these reasons, I strongly recommend, if the Project is approved, that there be no delay in carrying it out. I have no hesitation in saying that I think it is impossible to find a better Irrigation Project of this magnitude in Rajputana.

19. Irrigation takes time to develop, and until an Irrigation work is properly completed it cannot be expected to bring in any return; if therefore Irrigation is to be a success, once a work has been approved and sanctioned, the sooner it is completed the better. There should be no hesitation or delay in providing funds.

20. This brings us to the next difficulty. It is impossible for the Native States whose lands are affected by this Project, *viz.*, Mewar, Ajmer (Istimrari) and Jaipur, and probably Bundi and Tonk, to carry out such a large work, even if they combined. They need the help of the Imperial Government, and without this help there is no hope of anything being done.

21. The Report shows how the Engineering difficulties may be overcome; the difficulties to be now met are political and financial. If nothing better suggests itself may I suggest the following procedure:—

(1) It might be explained to the Native States that the Government desires to store all this water, which now goes to waste, not for its own benefit, but solely for the benefit of these States themselves, and comes forward to help them, because it sees that they are unable to do anything in the matter by themselves.

(2) That each Native State concerned is invited to be a partner or co-sharer in the Project, and to put whatever money they like into it. If they are unwilling or unable to provide the money, the Government to lend them money at the usual rate of interest for this work; and would itself provide whatever balance may be required.

(3) The work to be considered as a joint stock concern to be carried out and maintained by the Imperial Government.

(4) The water rate and revenue realized to be treated as profits on the concern and to be shared *pro rata* among the shareholders.

(5) Each State to have the option of paying off its own share, or the amount borrowed from Government, at any time. When all had been refunded the concern would belong to these Native States, who would share between them all profits according to the amount contributed by each.

(6) Any cases of reference between the States to be referred to the several Political Officers and to be settled by them, as similar cases are now dealt with.

22. It is unnecessary, perhaps, to point out the great political advantages which are secured by getting Native States to be associated together in a work of this nature, entirely for the good of their own States.

23. In conclusion, I desire to bring to notice the excellent work done by Mr. Manners Smith and his staff, in preparing this grand Project, which, it is hoped, before long will be carried out, and be the best monument that they could wish for.

S. S JACOB, COLONEL,

Consulting Engineer for Irrigation in Rajputana.

21*st November* 1904.

BANAS CANAL PROJECT.

REPORT.

REPORT.

In 1884 Colonel Sir Swinton Jacob, at that time Superintending Engineer of the Jaipur State, had a Project prepared for putting a masonry Weir across the River Banas, near the village of Khejri, just inside the British District of Ajmer and close to the Jaipur border, by which a portion of the flood water, and also the water which flows for some months after the floods, would be diverted to a Canal which it was proposed to take off on the right or south bank, for Irrigation; and also to ensure in years of scanty rainfall, by means of this Canal, all the village tanks within its influence being filled. History of the Project.

2. The Project was intended primarily to benefit Jaipur, but to obtain this object the Tonk and Bundi States had to be passed through, and were included in the Scheme. (See Plan No. 1).

3. There was no site for storage available at the head works of the Canal, and Colonel Jacob, in consequence, did not consider the Project a really good one, as in any Canal Project from the rivers of Rajputana, which are dependent on the rainfall, the flood water must be stored if the Rabi crop is to be irrigated.

4. This Project was brought to the notice of the Irrigation Commission when they visited Rajputana in October 1901, and the advisability of obtaining the sanction of the Mewar Durbar to a reconnaissance of the Banas was suggested, as from the map there seemed an excellent site for a large Storage Reservoir at Kokunda, where the Banas, after being joined by its tributaries the Berach and Kothari, flows through a gorge in the hills. From this Storage Reservoir it was thought a Canal could be taken on the left or north bank through Mewar and Ajmer, and the water let down till the site of the head works of Colonel Jacob's Project, or some suitable site near Kokunda, was reached for taking a Canal away on the right bank.

5. The Mewar Durbar were applied to, and kindly gave their consent to the reconnaissance; but after inspection the site at Kokunda was not approved. A very good site was, however, found at Amarpura, about 6 miles below the Kokunda gorge. (See Plan No. 1).

On the right bank high hills run parallel to the river, and on the left a range of low hills runs from Amarpura round to the north-west, *via* Kotaj and Khati, forming a natural bund (see Plan No. 2); and it is only the gap between this range and the high hills on the right, through which the river flows, that has to be closed.

6. This site was fixed on, and in 1901-1902 preliminary surveys were made, to furnish sufficient data to decide whether the Project was worth working out in detail.

Site at Amarpura inspected & approved by the Consulting Engineer for Irrigation in Rajputana.

7. In March 1903 the site at Amarpura was inspected and approved by Colonel Sir Swinton Jacob—who had in the meanwhile been appointed Consulting Engineer for Irrigation to supervise investigation of Protective Irrigation Works in Rajputana—and he directed that surveys should be made and detailed Plans and Estimates prepared.

Catchment Area.

8. The unintercepted Catchment Area at Amarpura (see Plan No. 1) is 5,600 square miles, as noted below:—

Total Catchment Area		Sq. miles	6,326
Deduct—			
Intercepted by the Girwar	Sq. miles	244	
,, ,, Rai Samand ...	,,	202	
,, by about 250 other tanks, say	,,	280	
			726
Total square miles ...			5,600

If the Projects on the Banas and Kothari River recommended by the Consulting Engineer (see Report on Irrigation in the Mewar State) are ever carried out, this Catchment Area will be further reduced by—

		Catchment Area.
Banas River—Namano Canal Project ...	Sq. miles	506
Kothari River—(*a*) Khalla Project ...	,,	198
(*b*) Meja Project ...	,,	435
Square miles ...		1,138

or to 4,462 sq. miles.

But this reduced Catchment Area will be sufficient for our requirements, and with the 26″ average rainfall of Mewar, a $5\frac{3}{4}$ per cent. run-off on this Catchment will fill the reservoir with the capacity proposed of 15,677 m. c. ft.

Water available for storage. Discharge during the rains of 1903.

9. As no record of the river discharges during the rains existed, observations were taken at Amarpura from July to October 1903, to note the rainfall, the daily measurements of depths of flow in the river, and also measurements of velocity. Though to be of practical value records for several successive years are necessary, the following is the result for the rains of 1903, as recorded in Appendix A :—

(*a*) The total rainfall at Amarpura was 31·39″ in excess of the average of the last 10 years in Mewar, which is 26″.

(*b*) The maximum rainfall occurred on 27th July when 1·06 fell in 35 minutes, equivalent to 2″ per hour.

(*c*) The highest flood occurred on 9th September, with a depth of $10\frac{1}{2}$ ft. and a discharge of 39,842 c. ft. per second.

(*d*) The total amount of water which passed down the river was 34.982 m. c. ft., equivalent to a run-off of nearly $8\frac{1}{2}$ per cent. from the 31·39″ rainfall, assuming this rainfall to hold good for the whole Catchment.

This amount is sufficient to fill the proposed Storage Reservoir nearly $2\frac{1}{4}$ times; even a 5 per cent. run-off from a 24″ rainfall will fill the Reservoir, and this may be safely calculated on.

Discharge after the Rains.

10. After the rains, from measurements of discharges taken previously by the Jaipur Public Works Department, we may safely calculate on 100 cusecs from October to the end of December, and 75 cusecs from January to March.

Water-spread & capacity at different Contours.

11. The following table gives the waterspread and capacities at the different Contours R, L. 505, has been assumed to be the level of the river bed at the Amarpura site :—

R. L.	Waterspread in s. ft.	Capacity in m. c. ft.
605	2,582,376,192	
		21844·12
595	1,786,447,872	
		14645·91
585	1,142,735,616	
		4942·14
580	834,121,728	
		3553·79
575	587,397,888	
		5105·92
565	433,787,904	
		3214·37
555	209,088,000	
		1586·28
545	108,168,192	
		899·07
535	71,647,488	
		645·38
525	57,429,504	
		479·51
515	38,472,192	
		192·36
505 (Bed Level)		
		57108·85

Flood Level.

12. In fixing our flood level we have to consider the villages that will be submerged and damaged, and from a reference to the Contour Plan of Tank Basin (Plan No. 2) it will be seen that we cannot allow our flood to be higher than R. L. 585, without damaging large villages like Chaprel, Nandrai and Bigod, and even at this level 37 villages will be submerged, or their lands damaged by the flood water. The names of these villages are given in Appendix B, and the matter is more fully referred to in para. 38.

Maximum Discharge.

13. It was thought that from the very large catchment area of 5,600 sq. miles more reliable results would be given by Craig's Formula and method for calculating the maximum discharge, than by Dicken's Formula, which depends on a value given to a variable co-efficient.

Mr. Craig has investigated the causes leading to the maximum flood discharge from drainage areas, with special reference to India; and his Formula is explained and the result worked out in Appendix C, giving a maximum discharge, in the present case, of 315,923 c. ft. per second. (See Appendix C and Plan).

Enquiries were also made as to the highest flood level from the villagers at Amarpura, and the mark pointed out by them corresponds to R. L. 546, and by Kutter's Formula the discharge at this level is 389,422 c. ft. per second. (See Appendix D).

As the villagers' mark is not absolutely reliable, the mean of this and of Craig's Formula, or 352,672 c. ft. per second, has been taken as the maximum flood we have to arrange to discharge. This is equivalent to a run-off of 5 per cent. from a rainfall of 2" per hour on the whole catchment of 5,600 sq. miles, and this, it is thought, will probably never be reached, certainly never exceeded.

Arrangements for Discharging maximum flood.

14. The length of Weir required to discharge this quantity with a 13 ft. head is 2,735 r. ft., but—

(*a*) The site is not suitable for a Weir of this great length.

(*b*) The bed of the river would gradually silt up in front of the Dam.

(*c*) With an open Weir we are only able to store up to Weir Level itself.

The Consulting Engineer therefore decided that we should discharge the maximum flood through :—

(*a*) Under-Sluices in the river portion of the Dam, each Sluice 25 ft. high × 5 ft. wide, fitted with Stoney's Patent Gates.

(*b*) A set of Automatic Flood Gates (Visvisvaraya's Patent) each 10 ft. wide and 8 ft. high—similar to those used on the waste Weir of Lake Fife, near Poona.

These automatic gates to be fixed at R. L. 572 (Weir Level), so that when closed we shall be able to store 8 ft. vertical depth of water above our original level, *viz.*, up to R. L. 580, for the same height of Dam.

Levels of Dam.

15. The following are the levels of the Dam as finally fixed :—

Crest of Dam	...	...	R. L. 593
Flood Level	...	...	,, 585
Full Supply Level	...	...	,, 580
Weir Level	...	...	,, 572
Bed Level of River	..	...	,, 505

16. The waterspread area of the Storage Reservoir at full supply level is 834,121,725 s. ft., or 30 square miles; and the capacity is 15676·68 m. c. ft., or allowing 100,000 c. ft. of water per acre, including absorption and evaporation, sufficient to irrigate 156,767 acres, or 245 sq. miles. **Area and Capacity of Storage Reservior.**

17. (*a*) Starting from the hills on the right bank of the River (see Plan No. 3) at chainage 50, the Dam, which will here be of masonry, crosses the river, which is 720 ft. wide (chainage 560-1,280), and continues in a straight line till the top of the left bank is reached at chainage 1,393. **The Dam.**

Here it follows a reverse S curve along the rocky ridge on which Amarpura village is built to chainage 2,680.

(*b*) From chainage 2,680-3,927, a gap between the Amarpura hill and the low range of hills on the east, which afterwards form a natural Dam, has to be crossed. Here there are fields of sandy soil, about 8 ft. in depth, overlying rock.

For this portion it is proposed to have an earthen Dam with a masonry Core Wall—

(*c*) From chainage 3,927-4,165, the Dam will be of masonry again, built into the hills, and the head-works of the high-level Canal will be fixed here.

(*d*) Another small portion of masonry Dam, 240 r. ft. in length, from chainage 4,270-4,540 will be required across a high-level gap in the hills to prevent the possibility of flood water getting round at this end; unless it is eventually decided to do away with the 8 Automatic Flood Gates on the right bank of the river, in which case a Weir, 300 ft. long, with crest cut down to R. L. 580 (full supply level) would be made here, and arrangements for passing the overflow water from this across the Canal below.

(*e*) The total length of the Dam is, therefore, 4,165 r. ft., of which 3,158 r. ft. will be of masonry throughout, and 1,247 r. ft., an earthen Dam with Core Wall.

18. Plan No. 4 is the Stability Diagram for the masonry Dam from chainage 560-1,280, the portion in which the Under-Sluices occur, and Plan No. 5 is the Stability Diagrams for the remaining portion of the Masonry Dam. The data on which the calculations for the Dam are framed are :— **Masonry Dam—Stability Diagrams.**

(1) That the depth of water in front may be as much as R. L. 585 (River bed = R. L. 505).

(2) That the specific gravity of the masonry is 2·24.

(3) That the pressure per sq. ft. on either toe should not exceed 8 tons.

(4) That the line of resistance should pass within the centre one-third of the Dam.

(5) When the Reservoir is dry it is assumed that there will be water up to level of Under-Sluices Sill R. L. 510.

Appendix E gives the calculation sheets which have been worked out for the masonry Dam, with a Memo. explaining the same.

Masonry Dam described.

19. The crest of the masonry Dam is R. L. 593 throughout, or 8 ft. above high flood level.

(*a*) From chainage 560-1,280, where the Under-Sluices occur, the top width is $21\frac{1}{4}$ ft., *viz.*, $12\frac{1}{2}$ ft. for road-way and $8\frac{3}{4}$ ft. for the Sluice Pits, into which the gates rise, with the masonry face wall in front of them. The Sluice Pits are necessary, in order that the Sluice Gates when raised may be comparatively in the dry, and to allow of them being examined, cleaned and painted when necessary; and that the hanging attachments may also be out of water.

(*b*) For the top 8 ft., *viz.*, from crest to H. F. Level, the front and rear faces of the Dam are vertical; below this the front face has a batter of 1 in 50, and the slope in rear is fixed by the section required from the stability diagrams.

(*c*) For the remaining portion (Weir) of the masonry Dam, with the automatic Gates, the top width is $12\frac{1}{2}$ ft., the roadway being carried on arched openings of 10 ft. span and 3 ft. rise, springing from Piers 3 ft. thick and 15 ft. high, built on the Weir (R. L. 572). In these openings the automatic Gates work, and through them the flood water is discharged.

Foundations for Masonry Dam.

20. The hill on the right bank of the river has hard conglomerate rock close to the surface, into which and on which the masonry Dam will be built.

Sounding and borings were taken at intervals across the river bed, and hard limestone similar to that on the left bank was found throughout the crossing, at a depth averaging $15\frac{1}{2}$ ft. below the river bed. The Plan on the opposite page shows exactly where the borings were taken, and the depth at which rock was found at each. The left bank is a ridge of hard solid limestone, and on this the line for the Dam has been taken.

There should, therefore, be little difficulty in the matter of foundations, and no fear of scour on the rear of the Dam from the flood water discharged by the Under-Sluices and automatic Gates.

Under-Sluices—Advantages of Stoney's Gates.

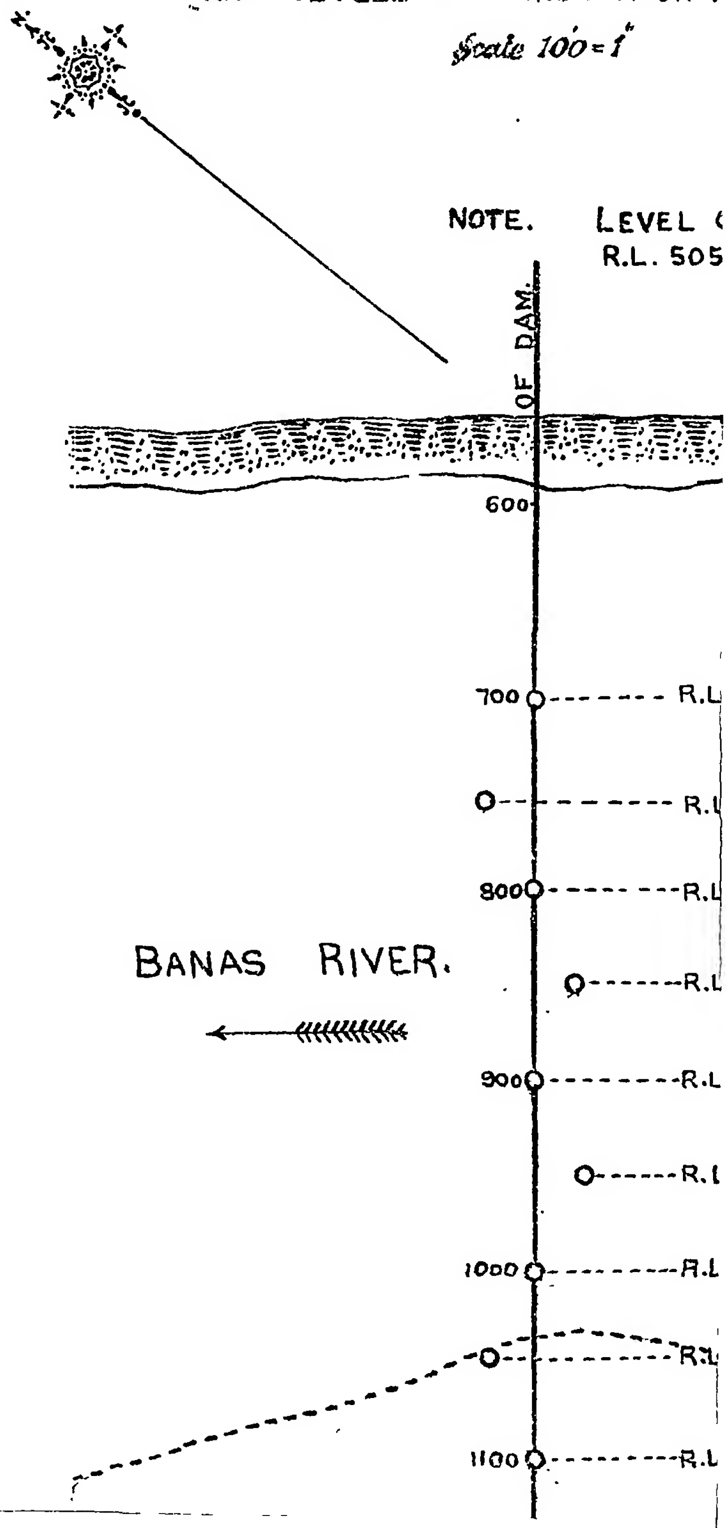
21. Plan No. 6 shows the arrangement proposed for the Under-Sluices. The advantage of using Stoney's Gates is, that friction is reduced to a minimum, and freedom of movement and facility of control is increased enormously.

Each gate hangs freely between jambs and each jamb is recessed, but instead of the gate being made to fit tight against the masonry

AMARPURA DAM.

PLAN SHOWING POSITION OF E
AND LEVELS AT WHICH ROCK W

Scale 100' = 1"



face as in the common Sluice Gate, a series of anti friction rollers are interposed between. The contact between the two faces, when the Sluice is being worked, is therefore not a sliding contact, which means excessive friction, but a rolling contact.

The rollers are not fixed to either face but are simply mounted in a hanging frame, so arranged that it may travel up and down with the gate, the rollers revolving easily on the faces during the operation. The load on the door does not pass through the axles of the rollers, friction and wear and tear being thus reduced to a minimum.

Object of the Under Sluices.

22. In addition to discharging and controlling a portion of the flood water, these Under-Sluices will prevent the accumulation of silt in the bed of the Storage Reservoir, and will also discharge the water required for the low-level Canal on the right bank of the river, the head-works of which will be at Ramgarh, about 10 miles lower down the river.

Number of Under-Sluices required and discharge.

23. It is proposed to have 28 Under-Sluices fitted with Stoney's Patent Gates in the portion of the masonry Dam across the river bed, from chainage 560-1,280. These will be $\overset{H}{25} \times \overset{B}{5}$, spaced 20 ft. clear apart, with sill level at R. L. 510, or 5 ft. above river bed, giving an effective head of 62·5 ft. when the maximum flood level, R.L. 585, is reached.

With this head each Sluice will discharge 6815·5 c. ft. per second, or the 28 gates will discharge 190,834 c. ft. per second.

But as is shown in Appendix F, when the maximum flood is discharged, the water in the river bed at rear of the Dam will rise to R. L. 542·3, and the Under-Sluice Drains will be submerged, reducing the effective head to 42·7 and the discharge per gate to 5636·75 c. ft. per second, or 157,827 c. ft. per sec. for the 28 gates.

Automatic Flood Gates.

24. The automatic Gates work in sets of 8, and either rise or fall as required. They are moved, *viz.*, opened or closed, by the vertical movement of a counter-weight float in the counter-weight cistern (See Plans 7 and 8). This cistern is on the down stream side of the Weir, and built so as not to obstruct the flow of water.

When a flood occurs and the water level rises to the level of the top of the gate (R. L. 580), water finds its way into the cistern by means of an opening in the centre piece. There is also an outlet pipe laid from the bottom of each cistern which can discharge freely at all times.

The outlet pipe from each cistern is always kept partly open, so that if the inflow from the Reservoir stops, or is stopped by closing the inlet valve, the cistern will always empty itself. When the inlet valve is opened however, the cistern gradually fills by the excess of the water which flows into the cistern over that discharged from it by the outlet pipe.

As stated above, when water rises to the level of the top of the gates, it flows into the cistern through the masonry inlet.

The water level in the cistern gradually rises and immerses the counter-weight, which in consequence floats and rises, and causes the gates to open by their own weight. When the flood subsides the water level in the reservoir falls below the level of the cistern inlet, so that the supply is cut off and the cistern is gradually emptied through the open outlet pipe. The counter-weight thus regains its full weight and moves vertically downwards, and the gates are closed.

The gates may be opened or closed mechanically at other times, whatever the level of the water may be, by working the Sluices in the valve chamber.

The counter-weight float is formed by a hollow water-tight vessel of any convenient shape and of the necessary calculated displacement and size, the required weight being obtained by adding sand or some other suitable ballast.

Number of Gates required and Discharge.

25. 104 of these gates, each $\overset{B}{10} \times \overset{H}{8}$, have been provided to discharge the balance of the flood water which does not pass through the Under-Sluices. One set of 8 falling gates will be fixed on the right bank from chainage 180-289, and the remaining 96 on the left bank on the curved portion of the masonry Dam from chainage 1,393-2,680.

The Dam here is all on hard sound rock, so that there is no fear of any damage occurring to the foundations by the fall of the flood water in rear of the Dam. Of the 96 gates, 40 will be falling and 56 rising, as the level of the rocky ridge prevents falling gates being used throughout.

The sill level of these gates will be R. L. 572 (weir level). When the maximum flood level R.L. 585 is reached. (See Appendix F).

(*a*) Each rising gate discharges 1656·3 c. ft. per second, or 56 gates discharge 92754·8 c. ft. per second.

(*b*) Each falling gate discharges 1431·12 c. ft. per second, or 48 falling gates discharge 69502·78 c. ft. per second.

The total discharge from the 104 gates is therefore 162,264 c. ft. per second.

It would be better if possible to have no gates on the right bank or at this end of the Dam; but there is no room for them elsewhere. The rock on this side the river is not so sound as on the left, and a Channel with masonry guide wall to prevent the flood water cutting away the hill in rear of the Dam would probably have to be constructed. The only alternative for these 8 gates is to cut away a Weir of 300 ft. length out of the rocky ridge at the N. end of the Dam (See para. 17 (*d*), with Sill at R. L. 580, or full supply level. A Weir of this length with 5 ft. discharge would pass 11,850 c. ft. per sec., which is slightly in excess of the discharge of the 8 gates, *viz.*, No. 8 × 1448·12 c. ft. per sec. = 11,585 c. ft. per second.

26. Appendix G gives tables which have been prepared to show the time required to fill the tank to high flood level under varying conditions. **Flood Control.**

The results may be summarised as follows :—

(*a*) Supposing the water in the Storage Reservoir to be at R. L. 510 (sill level of Under-Sluices), and a flood equal to the maximum flood of 1903, *viz.*, of 40,909 cusecs to occur with all the 28 Under-Sluices open, the water will never rise higher than R. L. 530·75, for at this level the inflow and outflow are equal. (See Appendix G, Table No. 4, column 4).

This flood may be taken as a normal flood, and the 28 automatic Gates are therefore more than sufficient for its control.

(*b*) Supposing when the water is at this level (R. L. 530·75) the maximum flood of 352,672 cusecs occurs.

With the 28 Under-Sluices kept open the water will rise to R. L. 572 (weir level) in 3 hours. (See Table No. 4).

(*c*) On the approach of this enormous flood all the 104 automatic Gates would have been opened mechanically, ready to give a free discharge when the water should have risen to R. L. 572.

Supposing the maximum flood still continues; with all the Under-Sluices and automatic Gates open, it will take 33 hours for the water to rise to R. L. 585 (high flood level). (See Table No. 5).

(*d*) As the springing level of the arches carrying the roadway over the automatic Gates is R. L. 587, should the flood still continue, the water would rise to this level, the absolute limit allowable, in another 30½ hours.

(*e*) We can therefore provide to discharge the maximum flood for 63½ hours in all, after it has risen to weir level, and as it is considered impossible for a flood of this magnitude ever to continue for more than 24 hours, the flood control provided may be accepted as sufficient.

If the flood lasted 24 hours, the water would rise to R. L. 583 and then begin to subside.

(*f*) To provide control for the maximum flood (352,672 cusecs) for an *indefinite* period, in addition to the Under-Sluices and flood gates, it would be necessary to cut away a Weir 1,125 r. ft., in length, with Sill at R. L. 580 (full supply level) on the rocky ridge at the N. end of the Dam.

With this Weir and the Under-Sluices and flood gates open when the flood had risen to R. L. 585 the discharge would be (See Appendix G, Table No. 5).

	Discharge, c. ft. per Sec.
Through 28 Under-Sluices (Under-Sluice Drains submerged)	157,827
56 Rising Gates	92,736
40 Falling Gates (8 gates would not be fixed on right bank if Weir proposed was constructed (See para. 25)	57,920
Weir 1,125 r. ft. in length, 5 ft. discharge... ..	44,437
TOTAL ...	352,920

From Cross Sections taken to see exactly what it would cost to cut away the ridge for a Weir of this length, and at the level proposed, it is found that 5,805,675 c. ft. of rock cutting would be required, and at Rs. 2 per 100 c. ft. the cost would be Rs. 1,16,114.

This does not include the cost of the masonry Escape, which would have to be constructed on the Main Canal to allow the flood water to cross before rejoining the river.

This very large expenditure is prohibitive, and the Weir proposed is considered unnecessary, but the proposal is noted to show that the possibility has been considered.

Earthen Dam with Core wall.

27. Plan No. 9 gives the type section of the earthen Dam with core wall which is proposed from chainage 2,680-3,927.

The core wall, which will be of masonry in lime and built in continuation of the masonry Dam, will be 2 ft. thick at top, starting at R. L. 595, forming a 2 ft. parapet for the roadway, which runs along the terrace at the top of the rear slope of earthwork.

The core wall increases 6″ in thickness at every 5 ft. depth, by 3″ offsets on either side, and the foundations will be taken down through the soft rock, which is found about 6′ below the ground surface right into the hard rock.

The earthwork in front has a 10 ft. berm at top, at R. L. 587, or 2 ft. above H. F. L. and a front slope of 3 to 1.

This berm and the front slope are protected by a 1 ft. layer of dry stone pitching on 6″ of kunkar or stone chips.

The earthwork in rear starts from R. L. 593 (crest of Dam) and is 10 ft. wide, with a rear slope of 2 to 1. An 8 ft. roadway runs along the 10 ft. terrace at the top connected with the roadway on the masonry Dams on either side.

Masonry wing walls are provided at either end of this portion of the Dam.

Head Sluices

28. The head sluice for the high level Canal is at chainage 4,000, at the north end of the Dam, with sill at R. L. 550; and Plans 9 and 10 show the arrangement proposed, which is similar to that at the Marikanave Dam in the Mysore State, a Plan of which was kindly sent by the Chief Engineer, Mysore.

This Canal is to irrigate land on the left bank of the river, as the low-level Canal will start from the right bank some 10 miles below the Dam, where the river leaves the range of hills on that bank; and the water for the low-level Canal will be discharged by the Under-Sluices (sill level R. L. 510) in the river bed.

Water available for Irrigation.

29. The water available for Irrigation will be :—

	m. c. ft.
(*a*) Water stored between R. L. 580-550 (sill of sluice, left bank Canal)	12,793
(*b*) Water store between R. L. 550-510 (sill of Under-Sluices)	3,013
Water brought into the Reservoir by natural flow—	
Oct. to Dec. (100 c. ft. per sec.) ... 3 × 259 =	877
January to March (75 c. ft. per sec.) .. 3 × 1,904 =	582
	m.c.ft. 17,265

Discharge required for Head Sluice—Left Bank Canal.

30. The land estimated as available for Irrigation on the left bank is 64,900 acres, or a little over 101 square miles, distributed as follows:—

	Sq. miles.
Mewar	26
Ajmer (Istimrari Estates) ...	37
Jaipur	38
	101

(See Appendix H).

Allowing 100,000 c. ft. of water per acre, we shall require 6,490 m. c. ft. for the high-level Canal, or 100 m. c. ft. of the water brought by the natural flow of the river, in addition to half the water stored between R. L. 580-550. The Irrigation will be for the Rabi crops lasting for four months, from November to February inclusive, so the Sluice must discharge the 6,490 m. c. ft. required for the area commanded in four months or—

$$D. = \frac{6{,}490}{4 \times 2{\cdot}592} \text{ (sec. per month).}$$

$$,, = \frac{6{,}490}{10{\cdot}368} = 626 \text{ c.ft. per second.}$$

This discharge is also more than sufficient to give half the area commanded a first watering of 6″ in 15 days in continuous flow—

$$D. = \frac{\overset{\frac{1}{2}\text{ Area in acres.}}{32450} \times \overset{\text{Sq. ft.}}{43560} \times \overset{\text{Ft.}}{\frac{1}{2}}}{\underset{\text{Days.}}{15} \times \underset{\text{H.}}{24} \times \underset{\text{M.}}{60} \times \underset{\text{Sec.}}{60}}$$

$$= \frac{706{,}761{,}000}{1{,}296{,}000} = 536 \text{ c.ft. per sec.}$$

As the Irrigation will be carried out by rotation, half the distributaries being open while the other half are closed, with this discharge we shall be able to give the whole area commanded a first watering of 6″ in 30 days, which is considered sufficient for the Rabi crop.

Design for Head Sluice.

31. The Sluice (See Plans Nos. 10-11) consists of a pair of Stoney's Gates $\overset{H}{9} \times \overset{B}{5\frac{1}{2}}$, spaced 6′ – 3″ apart, the one placed in front of the other, so that in case of accident to either gate the other can be closed.

These gates rise into Sluice Pits, built in front of the masonry Dam, similar to the arrangement for the Under-Sluices in the main Dam across the river.

A wrought-iron Grid, with vertical bars stiffened by cross girders, is provided in front of the gates to prevent branches, brushwood, or anything likely to danger the gates passing into the Sluice Drain, which runs through the masonry Dam and is connected with the main Canal.

These gates will work with an effective head of $25\frac{1}{2}$ ft. when the reservoir is full, and when the water is 1 ft. above the top of gate (R. L. 560) and the effective head is $5\frac{1}{2}$ ft. will discharge 751 c.ft. per second, which is slightly in excess of our actual requirements. (See Appendix F).

Main Canal and Distributaries on Left Bank of River.

32. Cross Sections of the country below Amarpura were taken at every $\frac{1}{2}$ mile (2,500 ft. apart) for 40 miles on the left bank of the river to give the contours of the land commanded, and to enable us to trace approximately the line for the main Canal and its distributaries.

The result is shown on Plans Nos. 15 and 17-20, and Appendix H gives the different type sections and discharges of the main Canal, and also of the Distributaries, with the probable area each will irrigate.

As in the case of the head Sluice the main Canal is designed to discharge sufficient water to give a 6″ watering in 15 days continuous flow, to half the area estimated as available for irrigation, and the irrigation will be carried out by rotation.

Plan No. 13 gives the type of Regulator proposed at each Distributary outlet; half of the Distributaries will be opened at a time, while the other half are closed, and they are designed to give a 6″ watering in 15 days to the land they command.

The Distributaries will follow the water-shed between the nullahs crossed by the main Canal, and run down towards the Banas or Khari as the case may be. (See Plan No. 15).

The slope of the country for the Distributaries is very great, and as their bed slope cannot be made more than 3 ft. per mile, a very large number of falls will be necessary. Appendix H gives a list of the falls required for each.

The main Canal line and the Distributaries have not been actually set out, so that the estimated cost for them is approximate, but it is thought will be found to be in excess of actual requirements.

Fall of Canal.

33. The main Canal for the first 28 miles has a fall of 1 ft. per mile, and from the 29th-63rd mile, when the Canal tails into the Dain River, the fall is 9″ per mile (5,000 ft.).

The fall of 1 ft. per mile to start with is necessary, as the site for crossing the Khari River is obligatory on account of—

(*a*) The large tributaries of this river which would have also to be crossed above.

(*b*) The Sawar hills below. (See Plan No. 1).

Cross Drainage Works.

34. This obligatory point gives the bed level of the Canal at the Khari, which is crossed by an aqueduct, and this must be high enough to allow the flood water of the Khari to pass below.

The aqueduct will be carried by 30 arches of 30 ft. span (see Plan No. 12), with 6 ft. rise, and springing level R. L. 513, or 13 ft. above lowest point of the river bed.

The site selected for the aqueduct is a good one, with rock on both banks, and cropping up or close below the river bed throughout, so that there will be no difficulty about foundations for the piers and abutments.

The proposals for the other cross drainage works are given in Appendix I, and a type section of an inlet and escape, where the Canal crosses nullahs at a low level, is given in Plan No. 14. In this case the flood water coming down the nullah in the rains will cross the Canal line, a paved crossing being constructed at Canal bed level, with piers 4 ft. apart, and 8 ft. high (1 ft. above full supply of Canal) on the down stream cross wall; below which, for the flood water to fall on, there is an apron of dry stone pitching, 3 ft. thick and 20 ft. long, with a line of blocks of concrete, each $\overset{L.}{6'} \times \overset{B.}{2'} \times \overset{D.}{4'}$—at the end, to prevent the pitching moving.

(*a*) After the rains, when the Irrigation season begins, wooden Gates $\overset{B.}{4'6''} \times \overset{H.}{8'}$—stiffened with battens and cross pieces, and hinged to an iron bar rivetted to the slabs on the top of the cross wall—will be raised and fixed in position between the piers with wooden bulli struts behind, and, if necessary, earth can be rammed in front, similar to the side slope of the Canal.

Across the top of the piers, slabs 3 ft. wide are fixed, forming a foot bridge across the nullah from bank to bank of Canal.

(*b*) On the up-stream nullah side of crossing a cross wall will be built up to Canal bed level, and at either bank a masonry abutment, with core walls carried into the Canal banks themselves.

The nullah bed will gradually silt up to Canal bed level; and, if found necessary, earthen banks will be constructed on either side the nullah till ground level 3 ft. above full supply level of Canal is reached, to prevent the possibility of the Canal water when it heads back up the nullah spilling over the country on either side. As the slope of the country from west to east, the direction of the nullahs crossed, is very great, the Canal water will only head back a short distance.

(*c*) On the down stream Canal side of crossing, a cross wall will also be built with piers carrying a foot bridge, but with wooden gates with counterweights, to facilitate raising and lowering, fitting into grooves in the piers. During the rains these gates will be lowered to prevent the nullah flood water passing down the Canal; and after the rains during the Irrigation season the gates will be kept open for the free passage of the Canal water down the Canal.

(*d*) Nothing will be done on the up-stream Canal side of crossing beyond pitching the banks, as the nullah floods are of short duration, and any water that headed back up the Canal would soon pass down again, and over the escape, without damaging the Canal banks.

Detailed estimates have been prepared for the Khari aqueduct, and the type inlet and escape, and from these the probable cost of each drainage work has been entered in the estimate.

Low-level Canal from Right Bank.

35. Time did not allow of surveys being taken for the Canal on the right bank, but sufficient infomation for our requirements is obtainable from the Jaipur Banas Canal Project.

The Banas continues its course for 10 miles below Amarpura before it leaves the hills on the right bank, and at this point, between Ramgarh (right bank) and Jamoli (left bank) villages, there is a good rocky crossing and a suitable site for a weir and head works for the Canal on the right bank.

Flying levels were taken along a base line from this site, with cross sections at every 4 miles, as far as Deoli 16½ miles below (See Plan No. 15), and are sufficient to show approximately the line a Canal would follow, at all events for the first 15 miles.

The weir across the river would probably be made with crest R. L. 502, or 8 ft. below sill of under-sluices at the Amarpura Dam, and 5 ft. shutters on the weir, which would be raised after the rains to hold up the water to R. L. 507.

The Canal would start with bed level R. L. 500, or 7 ft. below top of shutters, and would run at a higher level and commence irrigating sooner than the Canal surveyed for the Jaipur Project.

36. Of the water available for irrigation (See para. 28) the left bank canal requires half the water stored between R. L. 580-550. As the demand for irrigation will be simultaneous from both Canals, the two sluices will have to discharge equally, or the high-level Canal will not obtain its share. **Water available for Irrigation from Low-level Canal.**

This leaves for the low-level Canal—

November-February half water stored between R. L. 580-550 ... ... = 6,395

Add inflow from October-February $\overset{\text{m. c. ft.}}{877} + \overset{\text{m. c. ft.}}{388} = 1{,}265$

Less required by H. L. Canal ... ... − 100 = 1,165

7,560 m. c. ft.

to be discharged in four months, or $D = \frac{7{,}560}{10 \cdot 39} = 729$ c.ft. per second.

And at this rate $\overset{\text{cusecs}}{729} \times 2{\cdot}592 = 1{,}890$ m. c.ft. of the 3,195 m. c. ft. balance remaining in the storage reservoir can be used in March by the right bank Canal.

The total amount of water available is therefore 9,450 m. c.ft., and if we allow that 20 per cent. of this is lost by absorption in transit from Amarpura to the head works of the Canal, we have 7,560 m. c. ft. available for irrigation, or sufficient for 75,600 acres, or 118 square miles.

37. The Jaipur Project commanded an area of about 240 square miles :— **Estimated Cost of Jaipur Project and land commanded.**

Jaipur	50
Tonk	163
Bundi	27
Total ...	240

but it was thought that there would not be sufficient water for more than 50,000 acres, or 78 square miles.

The estimated cost was Rs. 9,65,000, that of the head works and cutting in the first 6 miles of the canal being unavoidably heavy.

A sum of Rs. 10,00,000 has been entered in the present estimate for head works and Canal on right bank, and this should be ample for our requirements.

38. Appendix B gives the names of the 37 villages which will be submerged if the Amarpura Storage Reservoir is constructed as proposed. **Compensation.**

The Mewar Durbar were asked to send a Revenue Officer to estimate the value and compensation that would have to be paid, but they finally decided that this was not necessary. With the exception of Hajibas and Khati, the villages are very small, and since the famine have only half their original population.

A sum of Rs. 1,11,000, averaging Rs. 3,000 per village, has been entered as the approximate amount that will have to be paid as compensation.

General abstract of cost.

39. The estimated cost of the Project is :—

	Amount.	Total.
DAM.	Rs.	Rs.
Masonry Dam	11,93,861	...
Earthen Dam with core wall	1,32,047	...
Under-Sluices	5,34,380	...
Automatic Gates	4,72,500	...
Head Works high-level Canal (left bank) ...	25,401	23,58,189
HIGH LEVEL CANAL, LEFT BANK.		
Main Canal	3,14,292	...
Distributaries	1,13,736	...
Khari Aqueduct	76,821	...
Cross Drainage Works	97,608	6,02,457
Low-level Canal, right bank	...	10,00,000
Compensation	...	1,11,000
GRAND TOTAL Rs. ...	...	40,71,646

Value of Water stored.

40. The value of water stored is 3,850 c. ft. per rupee.

Probable Revenue.

41. If the whole area for which we have water, on

Left bank	Acres	64,900
Right „	„	75,600
Total ...		140,500

is irrigated, @ Rs. 3 per acre (a low rate), a revenue of Rs. 421,500 should be realized, which gives a profit of 10¼ per cent. on the estimated cost.

Protective Value of work.

42. The work for its financial success depends on a sufficient number of cultivators to take up the land commanded, and make full use of the water available. If land now lying waste was given on easy terms at first there should be no difficulty in obtaining immigrant settlers.

The land is there, and the water, but the latter at present runs to waste each year, and is lost to Rajputana.

The river runs for weeks during the rains, even in years of scanty rainfall, and there should be no fear, with its very large catchment area, of the Storage Reservoir not filling every year.

The value of a work of this kind in a year of famine cannot be over-estimated.

As the work affects several States there will no doubt be great difficulties in arranging for its execution, and it is doubtful if without Government assistance the necessary funds will ever be forthcoming, but it is hoped that all these difficulties will eventually be overcome.

The Project is by far the largest Protective Irrigation work proposed for Rajputana, and if carried out will be one of the largest works of its kind in India.

Preparation of Project.

43. The Surveys were all made by Mr. T. Ruttonji, Assistant Engineer, and a party of Surveyors; and Mr. Ruttonji has also designed and prepared all the Plans and worked out the estimate for the Project, in accordance with the advice and directions given by the Consulting Engineer for Irrigation in Rajputana, and under the supervision of the Superintending Engineer, P. I. W. Rajputana.

SPECIFICATION.

Masonry Dam.

Dimensions.

44. The dimensions of the dam and all details are shown in the plans, and are to be strictly adhered to.

Foundations.

45. The foundations will be carried down in all cases to solid rock, well able to bear the weight of the masonry, and staunch enough not to leak under the pressure of the water impounded. The surface of the rock is to be cut into horizontal and vertical steps throughout the entire length of the dam.

The bed to present a rough surface so that the dam masonry and the solid rock shall break joint at their junction, and not have any through continuous joints.

No filling in the foundation is to be commenced till the excavation has been cleared of water and the solid rock properly prepared to receive it; if any flaws exist in the rock they must be cleared out and filled with cement or cement concrete.

The foundations must be kept clear of water during the execution of the masonry.

Uncoursed Rubble Masonry Bond & Laying.

46. The masonry of the dam will be of uncoursed rubble throughout. The stones to be carefully laid, so as to break joint as much as possible and solidly bedded with close joints.

No joint shall exceed half an inch in thickness. Chips of stone and spauls shall be wedged into the work wherever necessary, so as to avoid thick beds or joints of mortar. No dry work or hollow spaces shall be allowed in the masonry anywhere.

Every stone shall be set flush in mortar, smaller stones used in the filling being carefully selected to fit roughly the interstices between the larger ones.

All stones to be laid on their natural beds, about $\frac{1}{5}$ of the whole length of each course to be headers, and no header to be less than $2\frac{1}{2}$ ft. in length. The face-stones shall be selected for greater size, and good beds; they shall be laid so that they tail back and bond well into the work, and shall not be of greater height than either their breadth in face, or length of tail in the work.

As the faces batter the beds of the stones are to be at right angles to the batter. Stones to be thoroughly wetted before being laid in the work, and the proper watering of the masonry to be carefully attended to.

Pointing.

47. The exposed faces of the work (both front and rear) shall be carefully and neatly pointed with cement mortar in all joints, and round each stone, large and small.

The joints shall be raked out carefully at least one inch, and wetted and pointed with good fresh cement mortar carefully inserted, and the joints neatly finished off with the trowel.

Arch Masonry.

48. The arching for the under-sluices and sluice drains to be of Ashlar masonry, and for the sluice pit chambers and roadway arches, of block in course masonry.

All stones to be carefully and accurately wrought, giving the proper radiating joints, which shall not exceed $\frac{1}{8}$ inch for the Ashlar work and $\frac{1}{4}$ inch for the block in course.

In arches up to 2 ft. in thickness the stones shall be of the full thickness of the ring, beyond that thickness the stones to be laid header and stretcher alternately. Arches to be built on proper centres approved by the Engineer, and the mortar of the joints to be raked out when the centering is removed and neatly pointed with good cement mortar.

Lime Mortar.

49. Well burnt hydraulic lime is to be placed in the mortar mills in an even layer and to be well sprinkled with water. After an hour it is to be wetted thoroughly, and at the end of two hours it is to be stirred up and covered with water and allowed to slake for two hours; in all five hours' slaking, after which all unslaked heaps are to be removed. It is then to be ground for three hours, water being added when it becomes stiff.

Thoroughly wetted clear sand is then to be added evenly throughout the mill in the proportion of 2 of sand to 1 of slaked lime. The sand and lime to be ground together for two hours; in all five hours' grinding. If hydraulic lime is not obtainable, surkee to be used in place of sand.

If it is not used within six hours, the mortar to be heaped up about 3 ft. high, with water standing in a pool on the top. Mortar more than 48 hours old to be rejected.

The mortar to be tested for hydraulicity and strength, as directed by the Engineer.

50. The cement mortar for pointing to consist of equal parts of Portland cement and fine sand, the cement to be used within three hours after it leaves the mill. **Cement Mortar.**

Earthen Dam with Core Wall.

51. The side slopes to be marked out with deep trenches 1 ft. × 1 ft., and the surface of the ground between to be excavated 1 ft. deep, all the jungle and grass roots being removed to ensure proper footing. No earth to be excavated within 200 ft. of either slope. **Earth-work.**

The depth of excavation not to be more than 3 ft. near the dam, and to be increased as the distance recedes, to obtain the necessary earth. The earth to be deposited in layers not exceeding 9 inches in thickness, kept lower in the centre, and carefully consolidated.

52. The core wall in centre, to be of rubble stone set in lime mortar, only hard and durable stone to be used and the masonry to be kept wet during construction. All the stones to be hammer-dressed, laid on their natural beds, and to break joint in the same as well as in the successive courses. The faces of the masonry in contact with the earth to be kept quite rough and those remaining exposed to be pointed with lime mortar; care being taken that the filling on both sides of the core wall is carried up uniformly and is well rammed against both faces of the wall. **Masonry Core Wall.**

53. The foundation of core wall to be taken down through the soft rock till hard rock is reached, and the bottom 3 ft., to make a level bed, to consist of concrete, consisting of 3 parts of broken stones to 1 part lime mortar well mixed together, laid in 6 inch layers and well rammed. **Concrete.**

Canal.

54. All the cutting to be carried out as per sections, with required slope in bed, the excavated earth to be used in forming banks leaving a 15 ft. berm on either side of the Canal. **Earth Excavation.**

55. The masonry to be of coursed rubble in lime mortar, stones to be laid in horizontal courses not less than 6 inches in height; face stones to be squared on joints and beds, and the backing and face work well bonded together. Exposed faces to be pointed. **Aqueducts, Cross Drainage works.**

MATERIALS.

Stone, Lime and Wood.

56. Good building stone is procurable near the site; from the hills on the right bank of the river; and limestone at Paroli, where most of the lime for this part of the district is burnt, 2 miles from Amarpura. Wood for fuel is also procurable locally.

Stoney's Patent Gates.

57. For the Stoney's Gate, Messrs. Burn and Co., Calcutta, are the Sole Agents in India at present, and the rates entered in the estimate are those quoted by them. As it is understood that the Patent for these gates lapses very shortly, the rate will then no doubt be considerably reduced.

Automatic Flood Gates.

58. For the Automatic Flood Gates, Messrs. G. Gahagan & Co., Bombay, are the Agents, and the rates entered in the estimate are also those quoted by that firm. As the gates are more extensively used and made, the rate for these too should be reduced.

F. ST.-G. MANNERS SMITH,
SUPERINTENDING ENGINEER,
P. I. W., Rajputana.

AJMER:
17*th October* 1904.

ABSTRACT ESTIMATES.

No. 1—Estimate of Total Cost.

Main Heads.	Amount.	Total.
	Rs.	Rs.
DAM.—		
(a) Masonry Dam	11,93,861	
(b) Earthen Dam	1,32,047	
(c) Under-Sluice Gates	5,34,380	
(d) Automatic Flood Gates	4,72,500	
(e) Head Sluice for High-level Canal (Left Bank)	25,401	23,58,189
HIGH-LEVEL CANAL (LEFT BANK).—		
(a) Main Canal	3,14,292	
(b) Distributaries	1,13,736	
(c) Khari Aqueduct	76,821	
(d) Cross Drainage Works	97,608	6,02,457
LOW-LEVEL CANAL (RIGHT BANK).—		
Probable Cost (obtained from Report on the Banas Irrigation Project, Jaipur State) ...	......	10,00,000
COMPENSATION.—		
37 Villages submerged	3,000 each	1,11,000
GRAND TOTAL ...	......	40,71,646

T. RUTTONJI,
ASSISTANT ENGINEER,
Protective Irrigation Works, Rajputana.

30*th September* 1904.

F. ST.-G. MANNERS SMITH,
SUPERINTENDING ENGINEER,
Protective Irrigation Works.

17*th October* 1904.

No. 2—Masonry Dam, with Under-Sluices and Automatic Flood Gates.

Quantity.	Items.	Unit.	Rate.	Amount.	Total.
			Rs. A.	Rs.	Rs.
52,093 c.ft.	(1) Excavation in earth ...	1,000	5—0	261	
601,538 „	(2) Do. in sand ...	1,000	4—0	2,406	
526,469 „	(3) Do. in rock ...	100	4—0	21,059	
4,081,166 „	(4) Rubble Masonry, 1st class	100	25—0	10,20,292	
30,157 „	(5) Do do. 2nd class	100	20—0	6,031	
7,942 „	(6) Concrete	100	10—0	794	
4,557 „	(7) Cut-stone work	c.ft.	1—4	5,696	
78,536 „	(8) Arching	100	35—0	27,488	
3,972 s.ft.	(9) Paving	100	40—0	1,589	
9,648 c.ft.	(10) Kunker Roadway ...	100	10—0	965	
630 No.	(11) Cast-iron Standards ...	each	25—0	15,750	
12,480 r.ft.	(12) Piping	r. ft.	0—6	4,680	
......	(13) Pumping out water ...	lump	sum	25,000	
......	(14) Centring for Arches ...	lump	sum	5,000	
				11,37,011	
	Contingencies @ ...	100	5—0	56,858	
					11,93,861
28 No.	(15) Under-Sluice Gates—				
	Delivered on Ry., Calcutta	each	17,350—0	4,85,800	
	Freight and Erecting ...	10%	of cost	48,580	
					5,34,380
	(16) Automatic Flood Gates—				
104 No.	Delivered on Railway, Rupaheli	lump	sum	4,50,000	
	Freight and Erecting ...	10%	of cost	22,000	4,72,500
	Grand Total ...	..	...	...	22,00,741

No. 3—Earthen Dam.

Quantities.	Items.	Unit.	Rate.	Amount.	Total.
			Rs. A.	Rs.	Rs.
131,561 c ft.	(1) Excavation in earth ...	1,000	5—0	658	
107,203 „	(2) „ in rock ...	100	4—0	4,288	
42,559 „	(3) Concrete	100	10—0	4,256	
419,761 „	(4) Rubble Masonry... ...	100	18—0	75,557	
389 r.ft	(5) Coping	r. ft.	1—8	584	
5,983,977 c.ft.	(6) Earthwork	1,000	5—0	29,920	
168,008 sq. ft.	(7) Pitching	100	5—0	8,400	
84,005 c.ft.	(8) Kunker below pitching ...	100	1—8	1,260	
7,434 „	(9) Kunker Roadway ...	100	10—0	743	
1,859 „	(10) Dry Stone Retaining Wall.	100	5—0	93	
	Total ...	...	...	1,25,759	
	Contingencies @ 5 per cent. ...	...	...	6,288	
	GRAND TOTAL ...	...	...	...	1,32,047

No. 4—Head Sluice for High-level Canal (Left Bank) (for 1 Sluice with 1 pair of Gates only).

Quantity.	Items.	Unit.	Rate.	Amount.	Total.
			Rs. A.	Rs.	Rs.
25,338 c.ft.	(1) Excavation in rock ...	100	4—0	1,014	
32,330 „	(2) Rubble Masonry... ...	100	25—0	8,083	
1,669 „	(3) Arching	100	35—0	584	
150 „	(4) Kunker roadway... ...	100	10—0	15	
7 No.	(5) Cast-iron Standards ...	each	25—0	175	
168 r.ft.	(6) Piping	r. ft	0—6	63	9,934
......	Contingencies at 5 per cent.	...	...	...	467
......	(7) Sluice Gates	1 pair	...	...	15,000
	GRAND TOTAL ...	...	...	...	25,401

No. 5—High-level Canal (Left Bank).

Quantities.	Items.	Unit.	Rate.	Amount.	Total.
			Rs. A.	Rs.	Rs.
	1. MAIN CANAL—				
30,000 c.ft.	Excavation in rock	100	4—0	1,203	
59,625,150 ,,	Do. in earth	1,000	5—0	2,98,126	2,99,326
	Contingencies	100	5—0	..	14,966
	Total ...	...	...	...	3,14,292
	2. DISTRIBUTARIES—				
19 No.	Distributary Outlets	each	320—0	6,080	
21,046,248 c.ft.	Excavation in earth	1,000	4—0	84,185	
3,611 r.ft.	Masonry Falls	r. ft.	5—0	18,055	1,08,320
	Contingencies	100	5—0	...	5,416
	Total ...	...	...	...	1,13,736
	3. AQUEDUCT OVER KHARI RIVER—				
1 No.	As per detailed Estimate ...	...	...	73,163	73,163
	Contingencies	...	...	...	3,658
	Total ...	...	...	...	76,821
	4. CROSS DRAINAGE WORKS—				
1,040 r.ft.	10 Aqueducts	r. ft.	50—0	52,000	
7 No.	Inlets and Escapes	each	5,480—0	38,360	
1 No.	Over-Bridge *	lump	sum.	2,600	92,960
	Contingencies	...	...	...	4,648
	Total ...	...	...	...	97,608
	GRAND TOTAL ...	...	...	...	6,02,457

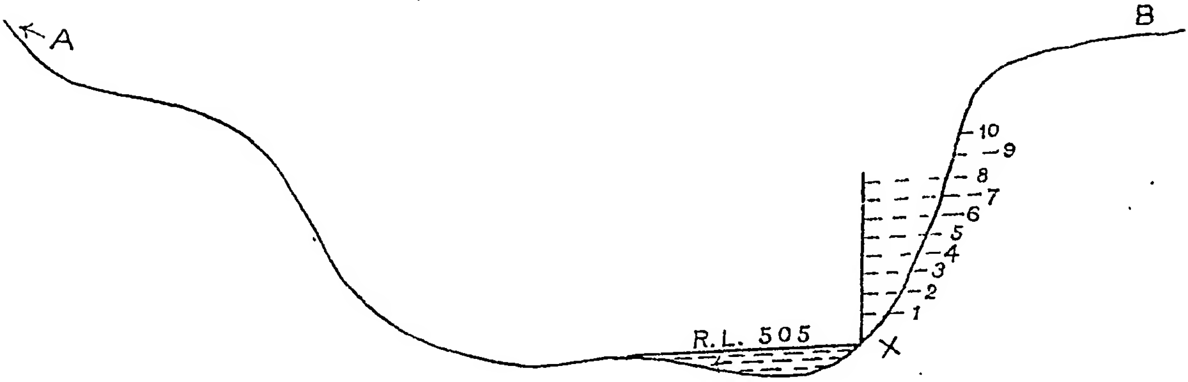
* Cost obtained from the Report on the Banas Irrigation Project, Jaipur State.

APPENDICES.

APPENDIX A.

Report on the Discharge of the Banas River at Amarpura, Mewar, at the proposed Dam Site in 1903.

In order to ascertain the total amount of water that passed down the Banas River at Amarpura during the rains, with a view to determine the possibility of filling the proposed tank, and also to ascertain the maximum discharge in c. ft. per second at H. F. L., on the date on which there was a maximum depth of discharge in the river, Sub-Overseer Amolak Chand was sent down to Amarpura, early in July 1903, to take daily measurements of the depths of flow in the river and also measurements of the velocity.



The low-water level in March 1902 was found to be approximately at R. L. 505 as at X (*vide* Sketch) along Dam line A—B.

This point was fixed upon as the zero of the scale, and in addition to a vertical gauge 8 ft. high fixed at this point, with its zero point corresponding with the level of X, another scale was marked with tar on the rock along the bank of the river from X towards station B at vertical intervals of 6 inches. In places where there was no rock the exact level was indicated in ft. and half ft. on circular discs, fixed to short legs, and embedded in the ground at the respective levels.

The result of the measurements taken are recorded in the accompanying statements, which also include a record of the daily rainfall at Amarpura during the monsoon of that year. From the latter we find that the total rainfall for the year amounted to 31·39 inches, and on one occasion the fall was very nearly 1″ in half an hour or about 2″ per hour. This is probably an abnormal fall, and undoubtedly only local in extent; or at any rate it is reasonable to assume that it was not distributed uniformly over the entire catchment area of about 5,600 sqr. miles. But assuming such to have been the case, the discharge over the catchment with a run-off of 5 per cent. amounts to 361,386 c. ft. per second. This is much less than the discharge arrived at by Dicken's Formula, but the run-off assumed is reasonable for so large a catchment area.

Calculations.—The calculations are based on Kutter's Formula for the discharge of water in channels; "n" the co-efficient depending on the lining of the channel has been taken = ·03, as the bed is sandy and irregular, and the up-stream reach is not straight. Readings were taken at intervals of six hours five times daily, *viz.*, (1) at 00 A.M., which corresponded with midnight of the previous day; (2) at 6 A.M.; (3) at 12 noon; (4) at 6 P.M. and (5) at midnight, which corresponded with 00 A.M. of the following day. The mean of these five readings has been taken as the depth at which the water flowed during the whole day, and this gives a sufficiently close approximation without unnecessarily increasing the calculations.

The fall of the river for about 8 miles up-stream above the point of observation was found to be about 3 ft. per mile, and this fall has been taken in the calculations.

The total theoretical discharge during the season amounted to about 34,000 m. c. ft., exclusive of the discharge below the zero of the scale, which was an appreciable amount, and continued (as has usually been the case) up to about the end of February of the following year. As the capacity of the tank at F. S. L. is about 15,600 m. c. ft. the tank could have been filled twice over during the monsoon, which may be taken as being a normal one.

The biggest flood during the year came down on the 9th September, when the river was flowing with a depth of 10 ft. 6 inches; and the discharge with this depth amounts to 39,842 c. ft. per second.

Velocity measurements were taken three times daily, *viz.*, at 6 A.M. at noon and at 6 P.M.

Whenever the depth of water at the time at which the velocity was measured corresponded with the mean depth of flow for the day, as given in Col. 6 (*vide* Abstract), the measured velocity has been entered in the Statement in Col. 11, and Col. 12 gives the mean of this measured velocity.

It will be noticed that at first there is a great difference between the mean theoretical velocity (Col. 8) and the mean of the measured velocity (Col. 12), which was due to the difficulty the Sub-Overseer experienced in throwing the floats into the middle of the stream and in getting them to go straight, as they were frequently driven towards the banks by contrary winds and currents. But as the Sub-Overseer became more expert it will be seen that later on there is very little difference between Cols. 8 and 12, and it may therefore be reasonably inferred that the theoretical velocity is, if not actually, at any rate very nearly equal to the actual velocity, and that therefore we may safely count on filling the tank at least once every year; for the discharge of the river during the year will, from all accounts never be less than half of what it discharged this year.

T. RUTTONJI,

ASSISTANT ENGINEER,

Protective Irrigation Works, Rajputana.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Date.	Rainfall.	Duration of Rainfall.	Maximum depth.	Minimum depth.	Mean depth.	Area at mean depth.	Theoretical velocity.	Q.	D (total discharge for the whole day.)	Measured surface velocity (V) at mean depth (col. 6.)	Mean of measured velocity (V) = ·8 V.	Q.	REMARKS.
		H. M.	Ft. in.	Ft. in.	Ft. in.	Sq. ft.	Ft.per.sec	Cusecs.	C. ft.	Ft. per. sec.	Ft. per. sec.	Cusecs.	
12th July 1903...	·11	0 50											
13th " " ...	·99	2 20											
14th " " ...	·48	5 50											
15th " " ..	·15	0 30											
18th " " ...	...	...	2 8	2 5	2 6	1407·5	1 83	2576	222,566,400	1·18	0·94	1323	
19th " " ...	·12	9 40	3 7	2 5	3 0	1754	2·15	3771	325,814,400				
20th " " ...	·11	5 52	3 7	2 6	3 0	1754	2·15	3771	325,814,400	1·32	1·06	1859	
21st " " ...	...	...	2 6	2 5	2 6	1407·5	1·83	2576	222,566,400				
22nd " " ...	·86	13 30	3 6	2 5	3 0	1754	2·15	3771	325,814,400	0·94	0·75	1316	
23rd " " ...	2·25*	3 45	3 4	2 10	3 0	1754	2·15	3771	325,814,400	...	...	...	*Very heavy; fell in 3h. 45m.
24th " " ...	·90	2 0	3 11	3 4	3 9	2280	2·58	5882	508,204,800	2·05	1·64	3739	
25th " " ...	·18	0 25	3 11	3 5	3 9	2280	2·58	5882	508,204,800				
26th " " ...	..	...	6 6	3 6	5 3	3351·5	3·38	11328	978,739,200				
27th " " ...	1·06†	0 35	4 11	3 10	4 3	2634	2·83	7454	644,025,600	1·98	1·58	4162	†Very heavy; fell in 35m.
28th " " ...	1·52	1 15	7 1	3 7	5 6	3533	3·45	12189	1,053,129,600				
29th " " ...	...	...	6 6	4 0	5 0	3171	3·17	10052	868,492,800				
30th " " ...	2·36	12 0	8 10	3 9	6 6	4262	3·90	16622	1,436,140,800				
31st " " ...	...	...	8 7	6 6	7 9	5183	4·38	22702	1,961,452,800				
1st Augt. 1903...	...	...	6 6	3 2	4 6	2812	2·95	8295	716,688,000				
2nd " " ...	1·44	7 40	3 4	3 0	3 0	1754	2·15	3771	325,814,400	2·14	1·71	2999	
3rd " " ...	...	...	8 8	3 0	6 3	4079	3·83	15623	1,349,827,200				
4th " " ...	...	...	7 0	6 0	6 3	4079	3·83	15623	1,349,827,200	3·45	2·76	11258	
5th " " ...	...	...	6 0	3 6	4 3	2634	2·83	7454	644,025,600	3·85	3·08	8113	
6th " " ...	...	...	3 6	2 6	2 9	1581	2·04	3225	278,640,000				
7th " " ...	3·57	14 15	2 6	2 6	2 6	1407·5	1·83	2576	222,566,400	2·56	2·05	2885	
8th " " ...	·62	10 30	6 0	2 6	4 0	2456	2·70	6631	572,918,400	3·50	2·80	6877	
9th " " ...	...	...	8 0	6 0	7 0	4629	4·17	19303	1,667,779,200				
10th " " ...	·75	4 25	7 0	5 6	6 3	4079	3·83	15623	1,349,827,200				
11th " " ...	...	...	5 6	3 3	4 0	2456	2·70	6631	572,918,400	2·79	2·23	5477	
12th " " ...	...	...	3 3	2 6	2 9	1581	2·04	3225	278,640,000				
13th " " ...	...	...	2 6	2 6	2 6	1407·5	1·83	2576	222,566,400				
14th " " ...	·62	1 45	...	......	......	......	......	......	175,132,800	......	......		On 14th and 15th August no discharge was taken. Discharge same as 16th entered.
15th " " ...			...	......	......	......	......	......	175,132,800				
16th " " ...	...	...	2 5	2 2	2 3	1236	1·64	2027	175,132,800				
17th " " ...	...	...	2 2	2 1	2 2	1179	1·64	1934	167,097,600				

18th „ „ ...	...	...	2 1	2 0	2 0	1064	1·46	1553	134,179,200				
19th „ „ ...	...	...	2 0	1 10	1 10	950	1·33	1263·5	109,166,400				
20th „ „ ...	...	...	1 10	1 9	1 9	893	1·30	1161	100,310,400				
21st „ „ ...	·25	0 50	1 9	1 9	1 9	893	1·30	1161	100,310,400				
22nd „ „ ...	·66	9 15	2 3	1 9	2 0	1064	1·46	1553	134,179,200				
23rd „ „ ...	·25	7 0	2 6	2 2	2 3	1236	1·64	2027	175,132,800				
24th „ „ ...	...	...	2 10	2 6	2 9	1581	2·04	3225	278,640,000	2·38	1·90	3004	
25th „ „ ...	...	...	2 9	2 6	2 6	1407·5	1·83	2576	222,566,400				
26th „ „ ...	·55	4 8	2 6	2 2	2 3	1236	1·64	2027	175,132,800				
27th „ „ ...	...	...	2 2	2 0	2 0	1064	1·46	1553	134,179,200				
28th „ „ ...	...	...	2 0	1 10	1 10	950	1·33	1236·5	109,166,400				
29th „ „ ...	...	...	1 10	1 8	1 9	893	1·30	1161	100,310,400				
‡30th „ „ ... to 5th Sept. 1903...	...	...	...	...	...	...	...	...	384,199,200	...	...	...	‡ No discharges were taken from 30th August to 5th September 1903, the average has therefore been taken for the period.
6th „ „ ...	1·05§	1 30	1 0	1 0	1 0	438	0·25	109·5	9,460,800	...	...	...	§ Very heavy rain.
7th „ „ ...	2·	18 25	1 8	1 6	1 6	719	0·30	216	18,662,400				
8th „ „ ...	2·97	17 50	5 6	4 0	4 3	2634	2·83	7454	644,025,600	3·85	3·98	8113	
9th „ „ ...	1·12	10 19	10 6	4 0	8 3	5555	4·60	25553	2,207,779,200				
10th „ „ ...	2·50‖	1 40	8 7	6 6	7 9	5183	4·38	22702	1,961,452,800	...	...	...	‖ Very heavy rain.
11th „ „ ...	...	...	7 9	6 6	7 0	4629	4·17	19303	1,667,779 200	4·27	3·42	15831	
12th „ „ ...	..	...	6 6	4 6	5 3	3351·5	3·38	11328	1,978,739,200				
13th „ „ ...	...	...	4 6	4 0	4 3	2634	2·83	7454	644,025,600				
14th „ „ ...	...	...	4 4	3 10	4 0	2456	2·7	6631	572,918,400	3·03	2·42	5944	
15th „ „ ...	...	...	3 10	3 0	3 6	2104	2·45	5155	445,392,000	2·32	1·86	3913	
16th „ „ ...	...	...	3 0	2 10	3 0	1754	2·15	3771	325,814,400				
17th „ „ ...	...	...	2 10	2 8	2 9	1581	2·04	3225	278,640,000				
18th „ „ ...	...	...	2 8	2 6	2 6	1407·5	1·83	2576	222,566,400				
19th „ „ ...	...	...	2 6	2 6	2 6	1407·5	1·83	2576	222,566,400				
20th „ „ ...	...	...	2 3	2 3	2 3	1236	1·64	2027	175,132,800				
¶21st „ „ ...	...	...	...	...	...	...	...	...	175,132,800	...	...	...	¶ There was no discharge taken on 21st September 1903.
22nd „ „ ...	1·60	1 45	2 6	2 2	2 3	1236	1·64	2027	175,132,800				
23rd „ „ ...	·35	0 40	2 7	2 6	2 6	1407·5	1·83	2576	222,566,400				
24th „ „ ...	...	...	3 0	2 7	2 9	1581	2·04	3225	278,640,000				
25th „ „ ...	...	...	3 0	3 0	3 0	1754	2·15	3771	325,814,400	2·82	2·25	4019	
26th „ „ ...	...	...	3 0	2 8	2 9	1581	2·04	3225	278,640,000	2·27	1·82	2877	
27th „ „ ...	...	...	2 8	2 3	2 6	1407·5	1·83	2576	222,566 400				
28th „ „ ...	...	..	2 3	2 2	2 3	1236	1·64	2027	175,132,800				
29th „ „ ...	...	...	2 2	2 2	2 2	1179	1·64	1934	167,097,600				
30th „ „ ...	...	...	2 2	2 1	2 1	1064	1·64	1553	134,179,200				
1st Oct. 1903...	...	...	2 1	1 11	2 0	1064	1·64	1553	134,179,200				
2nd „ „ ...	...	...	1 11	1 9	1 10	950	1·33	1263·5	109,166,400				
3rd „ „ ...	...	...	1 9	1 9	1 9	893	1·3	1161	100,310,400				
	31·39					Total discharge in 1903 ..			34,982,301,600				

T. RUTTONJI,

APPENDIX B.

Villages and Land submerged by Amarpura Storage Reservoir.

Serial Number.	Villages which will be submerged with their Land by the Amarpura Storage Reservoir.	Serial Number.	Villages whose Land is submerged, or damaged by Flood water.
1	Amarpura.	23	Pan-ki-Khera.
2	Asaori.	24	Mina Khera.
3	Baronda.	25	Megpura.
4	Chandpura.	26	Sakua.
5	Khera.	27	Bagri.
6	Kati, No. 1.	28	Khera.
7	Kati, No. 2.	29	Gunli.
8	Khera.	30	Etawa.
9	Berwa.	31	Banai-ki-Khera.
10	Khejri.	32	Hasera.
11	Bagri-ki-Khera.	33	Harmi Sarmi.
12	Bagro.	34	Ralaita.
13	Hazibas.	35	Belio.
14	Jeoria.	36	Thal.
15	Khera.	37	Jal-ki-Khera.
16	Sahorli.		
17	Khakunda.		
18	Lachmipura.		
19	Mandi.		
20	Sand.		
21	Khera.		
22	Khera, north of Mandi.		

APPENDIX C.

Craig's Formula for Discharges from Indian Drainage Areas (see Article in "Indian Engineer" of 4th May 1884).

For irregular catchments the perimeter has to be rectified by straight lines, and the whole area divided into triangles, with their apices at the point of discharge. The total discharge is the sum of the discharges of the component triangles.

$$\text{Discharge in c.ft. per second} = 2{\cdot}3\left\{560\ B \log L \left(\frac{L + \sqrt{L^2 + \frac{B^2}{16}}}{\frac{B}{4}}\right)\right\}$$

where L = distance from Apex to centre of base of triangle in miles.

B = the perpendicular from one of the base Angular parts, also in miles.

Applying this to catchment of Amarpura Project in Banas as per plan attached—

(1) Triangle 1—

$$D = 560 \times 10 \log 29 \left(\frac{29 \times \sqrt{29^2 + \frac{10^2}{16}}}{\frac{10}{4}}\right)$$

$$= 5{,}600 \log 29 \left(\frac{29 \times \sqrt{841 + \frac{100}{16}}}{2{\cdot}5}\right)$$

$$= 5{,}600 \log 29 \left(\frac{29 \times \sqrt{847{\cdot}25}}{2{\cdot}5}\right)$$

$$= 5{,}600 \log \frac{29 \times 58}{2{\cdot}5}$$

$$= 5{,}600 \log \frac{1682}{2{\cdot}5}$$

$$= 5{,}600 \log 672{\cdot}8$$

$$= 5{,}600 \times 2{\cdot}83$$

$$= 15{,}848 \text{ c.ft. per second.}$$

(2) Triangle 2—

$$D = 560 \times 30 \log 82 \left(\frac{82 + \sqrt{82^2 + \frac{30^2}{16}}}{\frac{30}{4}}\right)$$

$$= 560 \times 30 \log 82 \left(\frac{82 + \sqrt{6724 + \frac{900}{16}}}{7{\cdot}5}\right)$$

$$= 16{,}800 \log 82 \frac{(82 + \sqrt{6780{\cdot}25})}{7{\cdot}5}$$

$$= 16{,}800 \log 82 \frac{(164{\cdot}34)}{7{\cdot}5}$$

$$= 16{,}800 \log 1{,}796{\cdot}9$$

$$= 16{,}800 \times 3{\cdot}255$$

$$= 54{,}684 \text{ c.ft. per second.}$$

(3) TRIANGLE 3—

$$D = 560 \times 21 \log 101 \left(\frac{101 + \sqrt{101^2 + \frac{21^2}{16}}}{\frac{21}{4}} \right)$$

$$= 11760 \log 101 \left(\frac{(101 + \sqrt{10201 + \frac{441}{16}}}{5{\cdot}25} \right)$$

$$= 11760 \quad \log \quad 101 \quad \frac{(101 + \sqrt{10228{\cdot}56})}{5{\cdot}25}$$

$$= 11760 \quad \log \quad \frac{101 \times 202}{5{\cdot}25}$$

$$= 11760 \quad \log \quad 3886{\cdot}1$$

$$= 11760 \quad \times \quad 3{\cdot}59$$

= 42218 c. ft. per second.

(4) TRIANGLE 4—

$$D = 560 \times 12 \quad \log \quad 83 \left(\frac{83 + \sqrt{83^2 + \frac{12^2}{16}}}{\frac{12}{4}} \right)$$

$$= 6720 \log 83 \left(\frac{83 + \sqrt{6889 + \frac{144}{16}}}{3} \right)$$

$$= 6720 \log 83 \ \frac{(83 + \sqrt{6898})}{3}$$

$$= 6720 \log \frac{83 + 166}{3}$$

$$= 6720 \times \log 4592{\cdot}6$$

$$= 6720 \times 3{\cdot}662$$

= 24608 c. ft. per second.

TOTAL.

			C. ft. per second.
Triangle 1	...	...	15,848
Triangle 2	...	...	54,684
Triangle 3	...	...	42,218
Triangle 4	...	...	24,608
	Total	...	137,358

Maximum Discharge = 2·3 × 137358 = 315923 c. ft. per second.

APPENDIX D.

Maximum Discharge accepting mark shown by Villages at Amarpura, corresponding to R. L. 546.

USING KUTTER'S FORMULA.

$A = 36158$

$P = 1275$ ft.

Fall of river 3 ft. per mile.

$V = C\sqrt{RS}$

$$S = \frac{3}{5280} = \frac{1}{1760}$$

$$R = \frac{A}{P} = \frac{36158}{1275} = 28{\cdot}3592$$

$\sqrt{R} = 5{\cdot}32$

$$\sqrt{RS} = \sqrt{\frac{28{\cdot}3592}{1760}} = \sqrt{{\cdot}0161}$$

$$= {\cdot}1268 \text{ say } {\cdot}127$$

$$C = \frac{A + \frac{V}{N} + \frac{M}{S}}{1 + \left(A + \frac{M}{S}\right)\frac{N}{\sqrt{R}}}$$

$$= \frac{41{\cdot}6 + \frac{1{\cdot}811}{{\cdot}03} + \frac{{\cdot}00281}{\frac{1}{1760}}}{1 + \left(41{\cdot}6 + \frac{{\cdot}00281}{\frac{1}{1760}}\right)\frac{{\cdot}03}{{\cdot}532}}$$

$$= \frac{41{\cdot}6 + 60{\cdot}36 + 4{\cdot}94}{1 + (41{\cdot}6 + 4{\cdot}94){\cdot}0056}$$

$$= \frac{106{\cdot}90}{1{\cdot}26} = 84{\cdot}84$$

$V = C\sqrt{RS4} = 8{\cdot}84 \times {\cdot}127 = 10{\cdot}77$ ft. per second.

Q. (Maximum Discharge) $= A.\ V.$

$= 36158 \times 10{\cdot}77$

$= 389422$ c. ft. per second.

APPENDIX E.

Calculation Sheets for Masonry Dam.

MEMO. EXPLAINING THE CALCULATION SHEET.

Let B C D E. be any section of Dam. Axis is the vertical line passing through upper edge of Dam.

Column 1 is = A R. in feet.

Column 2 gives the number of cross sections into which the Dam is divided for convenience of calculation.

The sections are numbered from top of Dam.

Column 3 is the area of B C D E. in sqr. ft.

Column 4. Let G be the centre of gravity of B C D E., G H. is given in feet in column 4.

Column 5 is the moment of the weight of B C D E., (unit = weight of a c.ft. of masonry) round the axis, that is, its weight multiplied by G H.

Column 6. The inner slope of Dam is pressed by water.

Column 6 is the vertical factor of the water pressure on E B., and is equal to E J., multiplied by the distance of centre of B E., below water level. The unit of weight is the weight of a cubic foot of masonry.

Column 7 is represented by H K.

Column 8 is the product of columns 6 and 7.

Column 9 is the total vertical pressure on E D., due to forces on section B C D E. alone.

Column 10 is the total vertical pressure on E D., due to forces on section B C D E., as well as the section above it, *viz.*, A B C I.

Column 11. Let the forces mentioned in column 10 act at G′, then G′ H′. is given in column 11. This is obtained by totalling moments of vertical forces (column 12), divided by the total of vertical forces (column 10).

Column 12. This is the algebraical sum of columns 5 and 8, adding the moments of preceding sections also.

Column 13. This is the total horizontal factor of pressure of water on face A E and acts at ⅓rd A E above the point E. The unit is the weight of a cubic foot of masonry.

Column 14. This is ⅓rd the depth of E below water-level.

Column 15. O T is the horizontal force, O G′ (passing through the centre of gravity of all the vertical forces) is the vertical force. O R is the resultant.

Column 15 gives the distance S R.

Column 16. The effective force acting at point R is

$$\frac{R.}{\cos SOR} \quad \frac{R^2}{\sqrt{\text{vertical force.}}}$$

The unit of calculation till now was the weight of a cubic foot of masonry. It is changed into tons from this column.

Column 17 is equal to R D when tank is full, and R E when tank is dry.

Column 18 is equal to the length of base; that is E D.

Column 19 is the pressure at toe D, due to the force given in column 16 acting at point R. For tank dry the same is calculated at toe E :—

Weight of Sections from Top.	Number of Sections.	Area of Masonry in each Section.	Distance of its centre of gravity from axis	Moment.	Vertical factor of water pressure in c.ft. of Masonry.	Its distance from axis.	Moment.	Total vertical pressure in each Section in c. ft. of Masonry.	Total, including Sections above.
1	2	3	4	5	6	7	8	9	10
							Tank Full.		
8	1	170	10·625	1806·25	...	...	...	170	170
20	2	274·44	11·4	3128·616	0·643	0·12	·07716	275·083	445·083
30	3	260·9	12·75	3326·475	1·518	0·34	·51612	262·418	707·50
40	4	295·4	14·3	4224·22	2·411	0·54	1·30194	297·811	1005·312
50	5	334·9	16·05	5375·145	3·303	0·74	2·44422	338·203	1343·515
58	6	301·16	17·9	5390·764	3·286	0·92	3·02312	304·446	1647·961
70	7	522·84	20·72	10833·2448	6·0	1·12	6·72	528·84	2176·801
83	8	671·19	24·55	16477·7145	7·951	1·37	10·89287	679·141	2855·942
90	9	406·56	27·5	11180·400	4·906	1·57	7·70242	411·466	3267·408
100	10	635·65	30·1	19133·065	7·767	1·74	13·51458	643·417	3910·825
110	11	700·15	33·1	23174·965	8·661	1·94	16·80234	708·811	4619·636
							Tank Empty (above R.L. 510).		
8	1	170	10·625	1806·25	...	...	...	170	170
20	2	274·44	11·4	3128·616	...	...	...	274·44	444·44
30	3	260·9	12·75	3326·475	...	...	...	260·9	705·34
40	4	295·4	14·3	4224·22	...	...	...	295·4	1000·74
50	5	334·9	16·05	5375·145	...	...	...	334·9	1335·64
58	6	301·16	17·9	5390·764	...	...	...	301·16	1636·80
70	7	522·84	20·72	10833·2448	...	...	...	522·84	2159·64
83	8	671·19	24·55	16477·7145	...	...	...	671·19	2830·83
90	9	406·56	27·5	11180·400	0·219	0·07	·01533	406·779	3237·609
100	10	635·65	30·1	19133·065	1·071	0·24	·25704	636·721	3874·33
110	11	700·15	33·1	23174·965	1·964	0·44	·86416	702·114	4576·444

Its distance from axis.	Aggregate Moment.	Horizontal Pressure.	Its distance from base.	Distance between feet of vertical and resultant in each Section.	Effective force in tons weight = W.	U = Distance from outer edge.	L = Length.	Pressure on toe $\frac{2W}{L}\left(\frac{2L-3u}{L}\right)$
11	12	13	14	15	16	17	18	19
(SPECIFIC GRAVITY 2·24.)								
10·625	1806·25	...	...	...	10·625	10·625	21·25	0·5
11·087	4934·94316	32·143	4·000	0·28	27·922	12 88	24·49	0·962
11·678	8261·93128	108·036	7·333	1·17	45·118	14·4	27·69	1·433
12·421	12487·45622	228·571	10·667	2·45	65·809	15·88	31·39	2·223
13·297	17865·04544	393·75	14·000	4·12	90·875	17·22	35·59	2·809
14·114	23258·83256	558·035	16·667	5·7	114·191	18·82	39·70	3 324
15·634	34098·79736	1072·543	20·667	10·3	168·269	20·2	47·44	5·126
17·713	50587·40473	1569·471	25·000	13·9	231·311	22·6	55·82	6·509
18·906	61775·50715	1500·892	27·333	12·75	245·826	26·95	60·34	5·378
20·692	80922·08673	1889·285	30·667	15	299·665	29·2	66·79	6·177
22·537	104113·85407	2322·321	34·000	17·35	359·531	31·3	73·24	7·483
(SPECIFIC GRAVITY 2·24.)								
10·625	1806·25	...	...	...	10·625	10·625	21·25	0·5
11·103	4934·866	...	...	...	27·778	11·33	24·49	1·388
11·712	8261·341	...	...	...	44·084	12·12	27·69	2·187
12·476	12485·561	...	...	...	62·546	13·06	31·39	2·996
13·372	17860·706	...	...	...	83·478	14·25	35·59	3·747
14·205	23251·470	...	...	...	102·3	15·18	39·70	4·396
15·783	34084·7148	...	...	...	134·977	16·94	47·44	5·285
17·861	50562·4293	..	...	...	176·927	19·32	55·82	6·096
19·07	61742·84463	10·937	2·333	0·02	202·339	20·64	60·34	6·531
20·875	80876·16667	64·509	5·667	0·15	242·132	22·59	66·79	7·127
22·736	104051·99583	162·723	9·000	0·30	286·186	24·59	73·24	7·758

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APPENDIX. F.

Discharge through Under-Sluice Gates, Automatic Flood Gates, Head-Sluice for Canal, etc.

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(1) Discharge through Under-Sluices fitted with Stoney's Gates each $\overset{\text{B.}}{5} \times \overset{\text{H.}}{25}$.

(*a*) When flood has reached high flood level; discharge assumed to be *free.*

$Q = E\ A.$

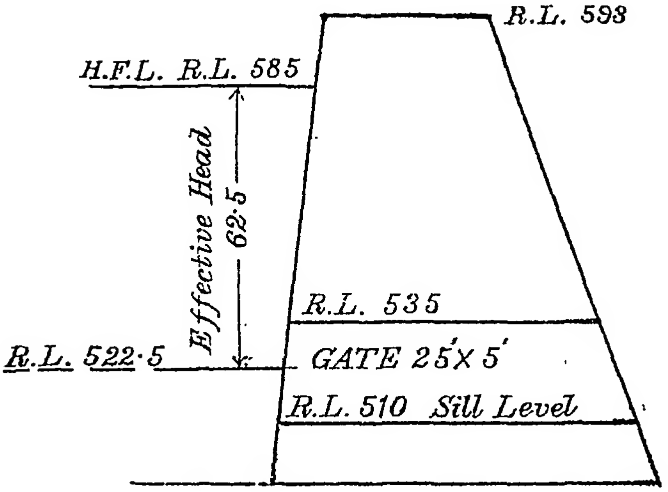
$E = V\ K.$

$V = 8{\cdot}025\sqrt{62{\cdot}5}$

$= 63{\cdot}4$

$K = {\cdot}86$

$E = 54{\cdot}524$



$Q = \overset{\text{E.}}{54{\cdot}524} \times \overset{\text{A.}}{125} = 6815{\cdot}5$ c. ft. per sec.

(*b*) With maximum flood discharge (352672 cusecs) when H. F. level is reached, water level in rear of Dam will be R. L. 542·3. (See Tables A and B).

Actual discharge will therefore be—

$Q = E\ A.$

$E = V\ K.$

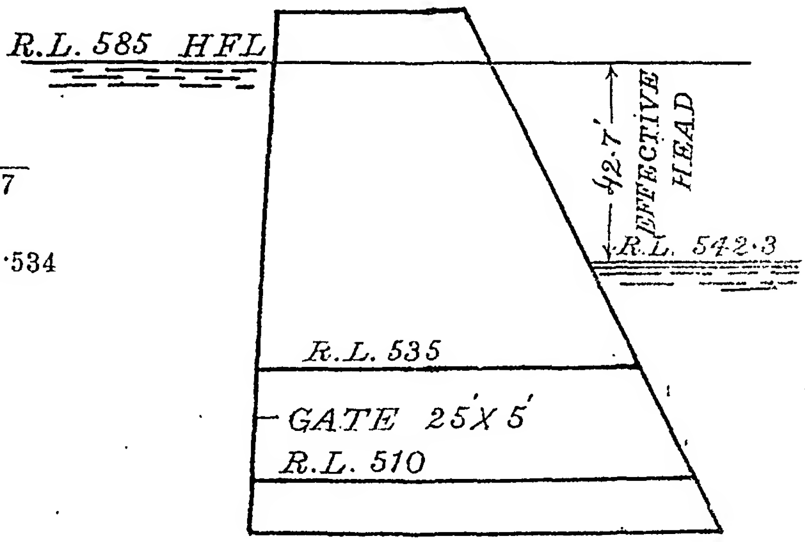
$V = 8{\cdot}025\sqrt{42{\cdot}7}$

$= 8{\cdot}025 \times 6{\cdot}534$

$= 52{\cdot}43$

$K = {\cdot}86$

$E = 45{\cdot}089$



$Q = \overset{\text{E.}}{45{\cdot}089} \times \overset{\text{A.}}{125} = 5636{\cdot}12$ c. ft. per sec.

(2) Discharge through automatic rising flood gate, when water has reached high flood level.

$Q = E\,A.$

$E = V\,K.$

$V = 8{\cdot}025\sqrt{9}$

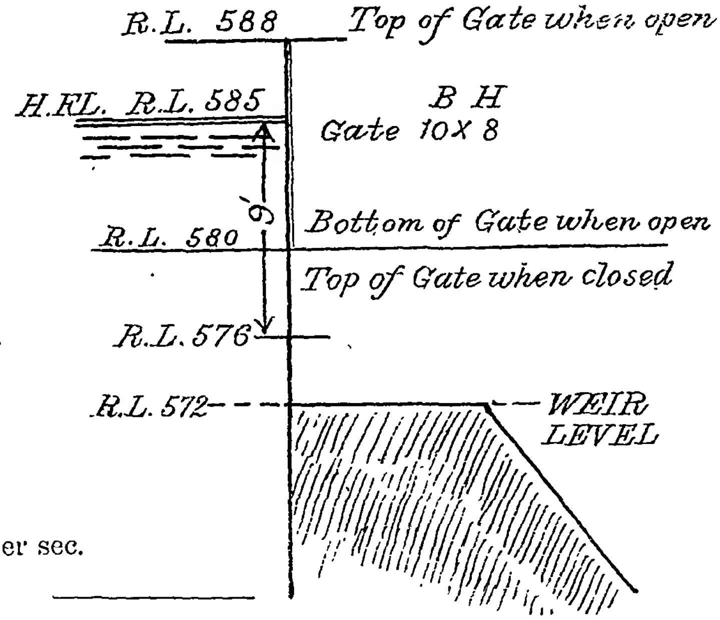
$= 24{\cdot}075$

$K = {\cdot}86$

$E = 20{\cdot}704$

$Q = \overset{E.}{20{\cdot}704} \times \overset{A.}{80.}$

$= 1656{\cdot}32$ c. ft. per sec.



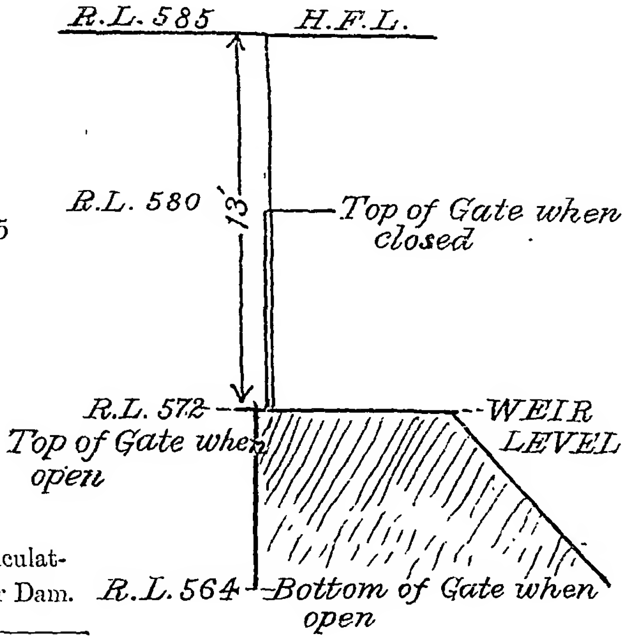
(3) Discharge through automatic falling flood gates, when water has reached high flood level.

$Q = 3{\cdot}09^{*}\,L\,H\sqrt{H}$

$= 3{\cdot}09 \times 10 \times 13 \times 3{\cdot}605$

$= 30{\cdot}9 \times 46{\cdot}865$

$= 1448{\cdot}12$ c. ft. per sec



* *Note.*—3·09 is the co-efficient used in calculating discharge from these gates at the Bhatgar Dam.

(4) Discharge through Head Sluice from High-level Canal, fitted with Stoney's Gates $\overset{H.}{9} \times \overset{B.}{5\frac{1}{2}}$; Sill level R. L. 550, when water is at its lowest level or at R. L. 560, one ft. above top of gates and sluice open.

$Q = E\,A.$

$E = V\,K.$

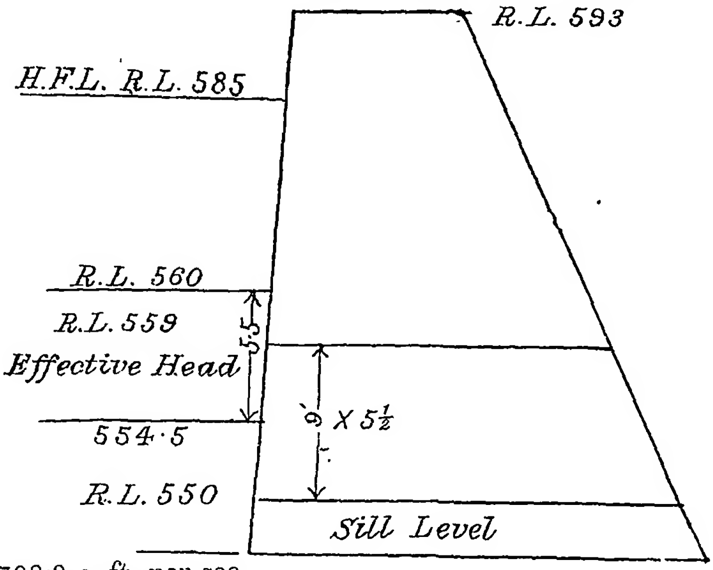
$V = 8{\cdot}025\sqrt{5{\cdot}5}.$

$= 8{\cdot}025 \times 2{\cdot}34.$

$= 18{\cdot}77.$

$K = {\cdot}86.$

$E = 16{\cdot}14.$



$Q = \overset{E.}{16{\cdot}14} \times \overset{A.}{49{\cdot}5} = 798{\cdot}9$ c. ft. per sec.

TABLE A.

Discharge of River at Amarpura.

For every foot rise from R. L. 510 (Sill level of Under-Sluices) to R. L. 546 (High Flood level mark shown by villagers).

R. L.	Area in s. ft.	Perimeter in r. ft.	Velocity in ft.	Discharge in c. ft. per sec.	REMARKS.
510	3,800	700	3·71	14,098	
511	4,496			19,000	
512	5,201			24,000	
513	5,916			29,000	
514	6,640			35,000	
515	7,371	744	5·55	40,909	H. F. L. in year 1903.
516	8,111			47,909	
517	8,861			54,900	
518	9,618			62,000	
519	10,383			69,500	
520	11,158	790	6·93	77,325	
521	11,943			82,300	
522	12,736			87,300	
523	13,536			92,500	
524	14,346			98,000	
525	15,163	838	8·16	123,730	
526	15,989			134,700	
527	16,825			145,700	
528	17,670			156,700	
529	18,523			167,700	
530	19,385	880	9·22	178,730	
531	20,258			189,700	
532	21,144			201,000	
533	22,044			213,000	
534	22,954			225,000	
535	23,882	960	9·94	237,387	
536	24,836			246,000	
537	25,816			255,000	
538	26,821			265,000	
539	27,871			275,000	
540	28,988	1,180	9·86	285,822	
541	30,146			300,000	
542	31,328			316,000	
543	32,531			332,000	
544	33,754			348,000	
545	34,994	1,290	10·45	365,687	
546	36,265	1,310	10·56	382,958	Highest F. L. ever known.

TABLE B.

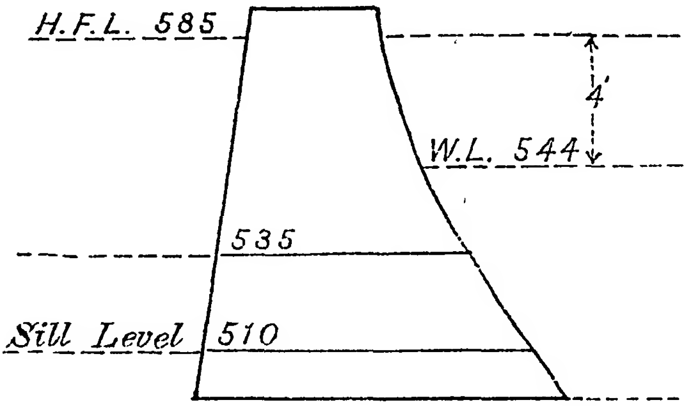
Table showing the Discharges and Water Levels in River in rear of Dam, and consequent effective heads for Under-Sluice Gates when water in tank is at different levels.

1	2	3	4	5	6	7
Water in Tank.	Height to which water will rise in rear of Dam.	Effective head for Discharge of Under-Sluice Gates.	Discharge through 28 Under-Sluice Gates in c. ft.	Discharge through 56 Rising Gates in c. ft.	Discharge through 48 Falling Gates in c. ft.	Total c. ft.
R. L.	R. L.					
530·75	515·0	No loss of head.	40,880	...	...	40,880
535	519·0		67,564	...	...	67,564
540	523·8	16·2	97,188	...	...	97,188
545	524·4	20·6	109,662	...	...	109,662
550	524·9	25·1	121,016	..	...	121,016
555	525·6	29·4	130,920	...	...	130,920
560	526·5	33·5	139,608	...	...	139,608
565	527·2	37·8	148,504	...	...	148,504
570	528·0	42	156,520	...	...	156,520
572	528·30	43·7	159,656	...	...	159,656
573	528·7	44·3	160,776	1,736	1,488	164,000
574	529·3	44·7	161,588	4,872	4,176	170,636
575	530·0	45	162,032	8,960	7,680	178,672
576	530·8	45·2	162,316	13,832	11,856	188,004
577	531·8	45·2	162,316	19,320	16,560	198,196
578	532·7	45·3	162,562	25,424	21,792	209,778
579	533·7	45·3	162,562	32,032	27,456	222,050
580	536·9	43·1	158,578	61,824	33,552	253,954
581	538·2	42·8	158,021	69,160	40,032	267,213
582	539·5	42·5	157,491	75,712	46,896	280,099
583	540·5	42·5	157,491	81,760	54,096	293,347
584	541·4	42·6	157,660	87,416	61,632	306,708
585	542·3	42·7	157,827	92,736	69,504	320,067
586	543·1	42·9	158,200	97,776	77,664	333,640
587	544·0	43	158,385	102,536	86,064	346,985

NOTE TO TABLE B.

When the maximum flood is being discharged the height to which the river will rise in rear of Dam has been worked out by trial and finally fixed, as shown in the following example :—

Suppose water in Storage Reservoir to have risen to R. L. 585 (H. F. L.) :—



Now with free discharge—

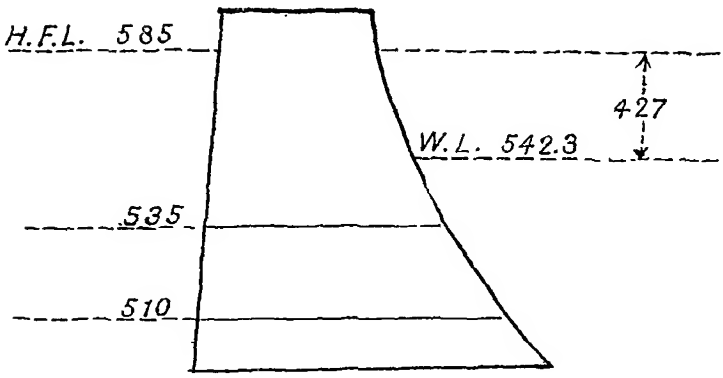
			Cusecs.
28 Under-sluices discharge	...	...	190,848
56 Rising gates ,,	...	...	92,736
48 Falling gates ,,	...	...	69,504
Total discharge		...	3,53,088

From Table "A" we find the river will discharge this with flood level between R.L. 544 and 545. Taking R. L. 544 the effective head would be 41 ft. and the discharge through—

				c.ft. per sec.
	28 Under-sluices with this head		...	154,588
These are not affected.	56 Rising gates	...	...	92,736
	48 Falling gates	...	...	69,504
	Total		...	316,828

Therefore the river will not rise as high as R. L. 544.

Taking R. L. 542·3 the effective head is—



and the discharge—

		c. ft. per sec.
Through 28 Under-sluices	... ...	*157,827*
„ 56 Rising gates	... ...	92,736
„ 48 Falling gates	... ...	69,504
	Total ...	320,067

and this corresponds to discharge of river with flood at R. L. 542·3. which is 320,800 cusecs.

APPENDIX G.

TABLES SHOWING TIME RESERVOIR WILL TAKE TO FILL TO FLOOD LEVEL UNDER VARYING CONDITIONS.

No. 1.

Table showing the time required for Storage Reservoir to rise to H. F. Level when 28 Under-sluices are opened as soon as water reaches to R. L. 572, and 56 Rising Gates and 48 Falling Gates open automatically when it reaches R. L. 580 (with free discharge for Under-sluices).

1	2	3	4	5 (M)	6	7 (N)	8	9 (O)	10	11			12		
R. L.	Depth over Weir in ft.	Mean Capacity.	Discharge through 28 Under-sluice Gates in c.ft. per second (with free discharge.)	Mean Discharge in c.ft. per second (with free discharge.)	Discharge through 56 Rising Gates in c.ft per second.	Mean Discharge in c.ft. per second.	Discharge through 48 Falling Gates in c.ft. per second.	Mean Discharge in c. ft. per second.	Rate at which Reservoir is filling in c.ft. per second. 352,672 — (M+N+O)	Time to raise water level 1 ft.			Total time.		
										H.	M.	Sec.	H.	M.	Sec.
572			169,820		...		...								
573	1	548,995,391	171,472	170,646	...	...	...	...	182,026	0	50	16	0	50	16
574	2	564,356,389	173,236	172,354	...	...	...	...	180,318	0	52	9	1	42	25
575	3	579,717,388	174,860	174,048	...	...	...	...	178,624	0	54	5	2	36	30
576	4	612,070,272	176,288	175,574	...	...	...	...	177,098	0	57	36	3	34	6
577	5	661,415,040	178,220	177,254	...	...	...	...	175,418	1	2	50	4	36	56
578	6	710,759,808	179,928	179,074	...	...	...	...	173,598	1	8	14	5	45	10
579	7	760,104,576	181,132	180,530	...	...	...	...	172,142	1	13	35	6	58	45
580	8	809,449,344	183,092	182,112	61,824	...	33,552	..	170,560	1	19	6	8	17	51
581	9	864,983,116	184,576	183,834	69,160	65,492	40,032	36,792	66,554	3	36	36	11	54	27
582	10	926,705,858	186,004	185,290	75,712	72,436	46,896	43,464	51,482	5	0	1	16	54	28
583	11	988,428,600	187,684	186,844	81,760	78,736	54,096	50,496	36,596	7	30	9	24	24	37
584	12	1,050,151,378	189,392	188,538	87,416	84,588	61,632	57,864	21,682	13	27	14	37	51	51
585	13	1,111,874,192	190,848	190,120	92,736	90,076	69,504	65,568	6,908	44	42	34	82	34	25

N.B.—As soon as water reaches the level of 585, rate of discharge through these openings will be 353,088 cusecs, or 416 cusecs more than maximum discharge expected from the Catchment.

No. 2.

Table showing the time required for Storage Reservoir to rise to H. F. L. when 28 Under-sluices, 56 Rising Gates, and 48 Falling Gates are opened (Mechanically) directly water reaches Weir Level of 572 (with free discharge for Under-sluices).

1	2	3	4	5 (M)	6	7 (N)	8	9 (O)	10	11			12		
R. L.	Depth over Weir in ft.	Mean Discharge in c.ft.	Discharge through 28 Under-sluice Gates in c.ft per second (free discharge.)	Mean Discharge in c.ft. per second (with free discharge.)	Discharge through 56 Rising Gates in c.ft. per second.	Mean Discharge in c.ft. per second.	Discharge through 48 Falling Gates in c.ft. per second.	Mean Discharge in c. ft. per second.	Rate at which Reservoir is filling in c.ft. per second 352672 – (M+N+O).	Time to raise water level 1 ft.			Total time.		
										H.	M.	Sec.	H.	M.	Sec.
572			169,820		0·00		0·00								
573	1	548,995,391	171,472	170,646	1,736	868	1,488	744	180,414	0	50	43	0	50	43
574	2	564,356,389	173,236	172,354	4,872	3,304	4,176	2,832	174,182	0	54	0	1	44	43
575	3	579,717,388	174,860	174,048	8,960	6,916	7,680	5,928	165,780	0	58	17	2	43	0
576	4	612,070,272	176,288	175,574	13,832	11,396	11,856	9,768	155,934	1	6	6	3	49	6
577	5	661,415,040	178,220	177,254	19,320	16,576	16,560	14,208	144,634	1	16	13	5	5	19
578	6	710,759,808	179,928	179,074	25,424	22,372	21,792	19,176	132,050	1	29	43	6	35	2
579	7	760,104,576	181,132	180,530	32,032	28,728	27,456	24,624	119,790	1	45	45	8	20	47
580	8	809,449,344	183,092	182,112	61,824	46,928	33,552	30,504	93,128	2	24	51	10	45	38
581	9	864,983,116	184,576	183,834	69,160	65,492	40,032	36,792	66,554	3	36	36	14	12	14
582	10	926,705,850	186,004	185,290	75,712	72,436	46,896	43,464	51,482	5	0	1	19	12	15
583	11	988,428,600	187,684	186,844	81,760	78,736	54,096	50,496	36,596	7	30	9	26	42	24
584	12	1,050,151,378	189,392	188,538	87,416	84,588	61,632	57,864	21,682	13	27	14	40	9	38
585	13	1,111,874,192	190,848	190,120	92,736	90,076	69,504	65,568	6,908	44	42	34	84	52	12

N.B.—As soon as water reaches the level of 585, rate of discharge through all these openings will be 353,088 cusecs, or 416 cusecs more than maximum flood discharge expected from the Catchment.

No. 3.

Table showing the actual time required for Storage Reservoir to rise to H. F. L. when 28 Under-sluice Gates are opened when water reaches 572 (Weir Level), and 56 Rising Gates and 48 Falling Gates open automatically when it rises to R. L. 580.

(Note.—The 28 Under-sluice Drains are submerged and their effective head and discharge is consequently reduced.)

1	2	3	4	5 (M)	6	7 (N)	8	9 (O)	10	11			12		
R. L.	Depth over Weir in ft.	Mean Capacity in c.ft.	Discharge through 28 Under-sluice Gates in c.ft. per second.	Mean Discharge in c.ft. per second.	Discharge through 56 Rising Gates in c.ft. per second.	Mean Discharge in c.ft. per second.	Discharge through 48 Falling Gates in c.ft. per second.	Mean Discharge in c.ft. per second.	Rate at which Reservoir is filling in c.ft. per second 352,672 − (M+N+O.)	Time to raise water level 1 ft.			Total time.		
										H.	M.	Sec.	H.	M.	Sec.
572			159,656		...		...								
573	1	548,995,391	161,112	160,384	...	...	...	...	192,288	0	47	35	0	47	35
574	2	564,356,389	162,680	161,896	...	..	...	...	190,776	0	49	18	1	36	53
575	3	579,717,388	164,712	163,696	...	...	...	...	188,976	0	51	7	2	28	0
576	4	612,070,272	165,760	165,236	...	...	...	..	187,436	0	54	25	3	22	25
577	5	661,415,040	167,345	166,552	...	...	...	...	186,120	0	59	13	4	21	38
578	6	710,759,808	168,916	168,130	...	...	...	...	184,542	1	4	11	5	25	49
579	7	760,104,576	170,293	169,604	...	...	...	...	183,068	1	9	12	6	35	1
580	8	809,449,344	158,578	164,435	61,824	...	33,552	...	188,237	1	11	41	7	46	42
581	9	864,983,116	158,021	158,299	69,160	65,492	40,032	36,792	92,089	2	36	32	10	23	14
582	10	926,705,858	157,491	157,756	75,712	72,436	46,896	43,464	79,016	3	15	28	13	38	42
583	11	988,428,600	157,491	157,491	81,760	78,736	54,096	50,496	65,949	4	9	48	17	48	30
584	12	1,050,151,378	157,660	157,575	87,416	84,588	61,632	57,864	52,645	5	32	27	23	20	57
585	13	1,111,874,192	157,827	157,743	92,736	90,076	69,504	65,568	39,285	7	51	42	31	12	39

N.B.—When water reaches R. L. 585, rate of discharge will be 320,067 cusecs, or 32,605 cusecs less than maximum flood discharge.

No. 4.

Table showing the actual time required for Storage Reservoir to rise to Weir level R. L. 572, from 530·75, when Under-sluice Gates are opened. That is the Reservoir is filled to R. L. 530·75, and maximum flood, 352,672 cusecs, is coming in and Under-sluice Gates are opened.

(Note.—Under-sluice Drains become submerged when water level reaches R. L. 540, and the effective head and discharge are consequently reduced.)

1	2	3	4	5 (M)	6	7	8	9	10	11	12
R. L.	Depth under Weir in ft.	Mean Capacity c. ft.	Discharge through 28 Under-sluice Gates c. ft. per sec.	Mean Discharge c.ft. per sec.					Rate at which Reservoir is filling in c.ft. per cusec 352,672-M.	Time to raise water level to different contours.	Total time.
										H. M. Sec.	H. M. Sec.
530·75	41·25		40,880								
535	37	68,626,165	67,564	54,222	...	...	...	...	298,450	0 3 49	0 3 49
540	32	80,777,664	97,188	82,376	...	...	...	...	270,296	0 4 59	0 8 48
545	27	99,038,016	109,662	103,425	...	...	...	...	249,247	0 6 37	0 15 25
550	22	133,398,144	121,016	115,339	...	...	...	...	237,333	0 9 22	0 24 47
555	17	183,858,048	130,920	125,968	...	...	...	...	226,704	0 13 31	0 38 18
560	12	265,262,976	139,608	135,264	...	...	...	...	217,408	0 20 20	0 58 38
565	7	377,612,923	148,506	144,056	...	...	...	...	208,616	0 30 10	1 28 48
570	2	472,190,400	156,520	152,512	...	...	...	...	200,160	0 39 19	2 8 7
572	0·00	525,953,894	159,656	158,088	...	...	...	...	194,584	0 45 3	2 53 10

No. 5.

Table showing the actual time required for Storage Reservior to rise to H. F. L. when 28 Under-sluice Gates, 56 Rising Gates and 48 Falling Gates are opened at the same time, *i. e.*, when water reaches R. L. 572—(Weir Level).

(Note.—The 28 Under-sluice Drains are submerged, and their effective Head and Discharge is consequently reduced).

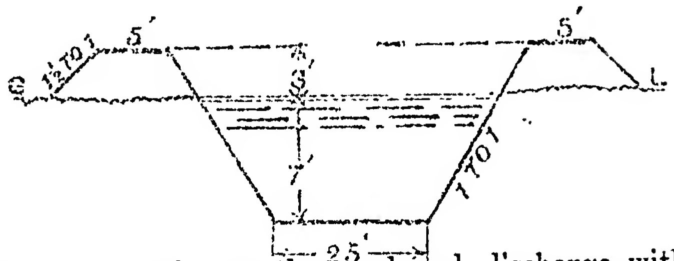
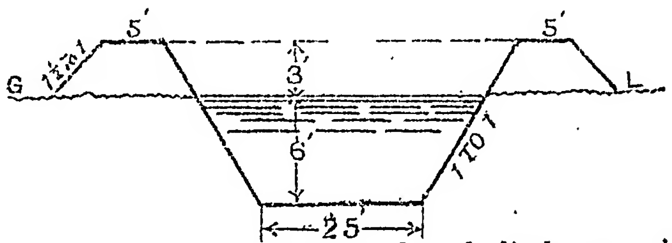
1	2	3	4	5 (*M*)	6	7 (*N*)	8	9 (*O*)	10	11			12		
R. L.	Depth over Weir in ft.	Mean Capacity c.ft.	Discharge through 28 Under-sluice Gates in c.ft. per second.	Mean discharge in c.ft. per second.	Discharge through 56 Rising Gates in c.ft. per second.	Mean discharge in c.ft. per second.	Discharge through 48 Falling Gates in c.ft. per second.	Mean discharge in c.ft. per second.	Rate at which Reservoir is filling in c.ft. per second 352,672—(M+N+O.)	Time to raise water level 1 foot.			Total time.		
										H.	M.	Sec.	H.	M.	Sec.
572			159,656		0·00		0·00								
573	1	548,995,391	160,776	160,216	1,736	868	1,488	744	190,844	0	47	57	0	47	57
574	2	564,356,389	161,588	161,182	4,872	3,304	4,176	2,832	185,354	0	50	44	1	38	41
575	3	579,717,388	162,032	161,810	8,960	6,916	7,680	5,928	178,018	0	54	16	2	32	57
576	4	612,070,272	162,316	162.174	13,832	11,396	11,856	9,768	169,334	1	0	14	3	33	11
577	5	661,415,040	162,316	162,316	19,320	16,576	16,560	14,208	159,572	1	9	4	4	42	15
578	6	710,759,808	162,562	162,439	25,424	22,372	21,792	19,176	148,685	1	19	40	6	1	55
579	7	760,104,576	162,562	162,562	32,032	28,728	27,456	24,624	136,758	1	32	38	7	34	33
580	8	809,449,344	158,578	160.570	61.824	46,928	33,552	30,504	114,670	1	57	39	9	32	12
581	9	864,983,116	158,021	158,299	69,160	65,492	40,032	36,792	92,089	2	36	32	12	8	44
582	10	926,705,858	157,491	157,756	75,712	72,436	46,896	43,464	79,016	3	15	28	15	24	12
583	11	988,428,600	157,491	157,491	81,760	78,736	54,096	50,496	65.949	4	9	48	19	34	0
584	12	1,050,151,378	157,660	157,575	87,416	84,588	61,632	57,864	52,645	5	32	27	25	6	27
585	13	1,111,874,192	157,827	157,743	92,736	90,076	69,504	65,568	39,285	7	51	42	32	58	9

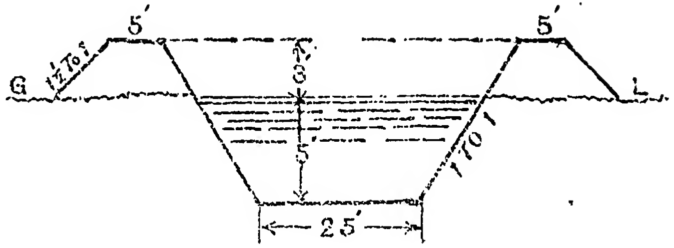
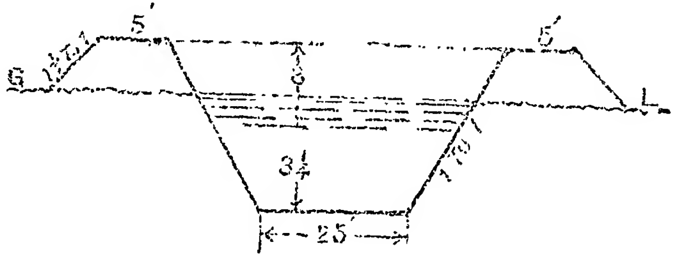
N.B.—When water reaches R. L. 585, rate of Discharge will be 320,067 c.ft. per second, or 32,605 Cusecs less than maximum Flood Discharge.

APPENDIX H.

TYPE SECTIONS OF MAIN CANAL AND DISTRIBUTARIES, WITH DISCHARGE OF AREA COMMANDED.

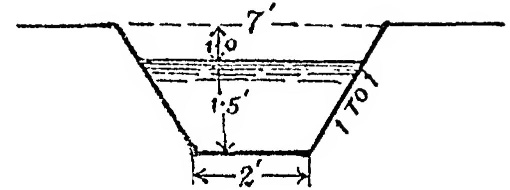
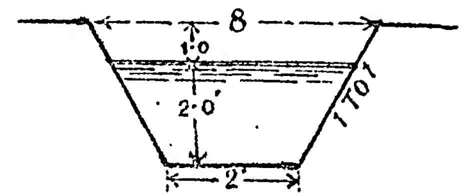
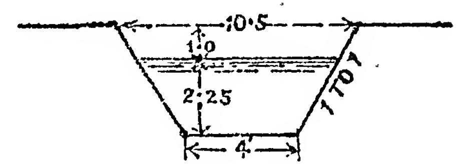
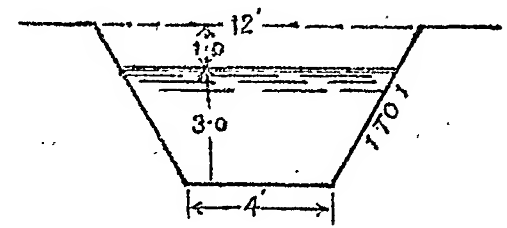
Type Sections of Main Canal and Distributaries, with Discharge and Area commanded. Class II (above the average).

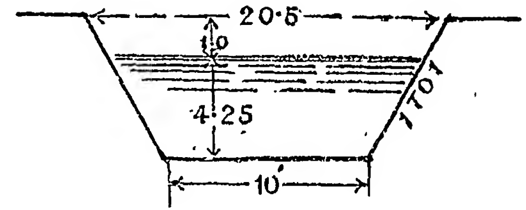
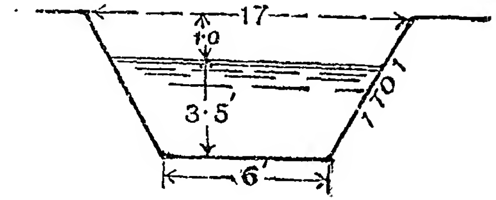
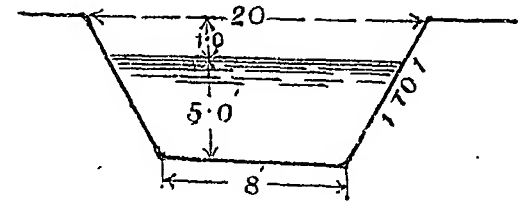
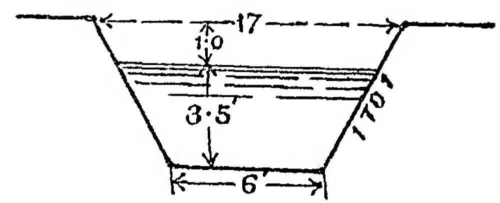
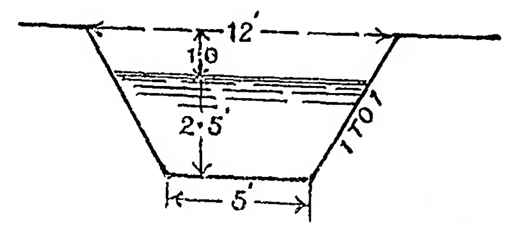
Sections irrigated by Distributaries. (See Plan No.).	Length of Canal at end of Section.	Total required discharge of all the distributaries in these Sections, to give a 6″ watering over irrigable area in 15 days.	Period during which the Distributaries in these Sections will be opened in one month.	Average discharge of Canal from commencement and end of Section.	Type Section of Canal for these Sections.
	Miles.	C. ft. per sec.		C. ft. per sec.	
A. B. C. & D.	17	117·6	1st half (15 days.)	616	
E.	21·9	159·6	2nd Do.	616	Bed fall = 0·2 ft. per thousand and discharge with this section, and 7 ft. depth = 618·2 c.ft. per sec.
F.	25·5	70·6	1st Do.	467	
G.	27·85	171·4	2nd Do.	467	Bed fall = 0·2 ft. per thousand and discharge with this section, and 6 ft. depth = 472 c.ft. per sec.

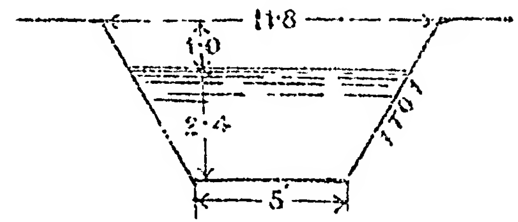
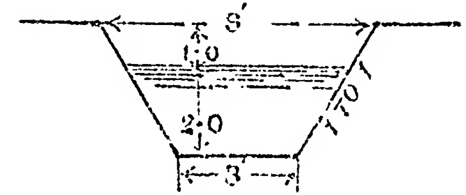
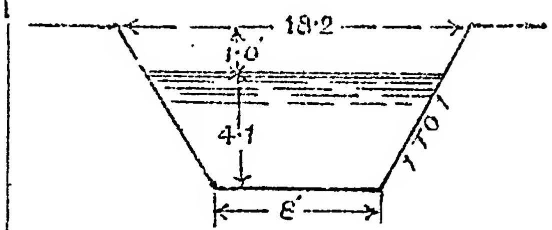
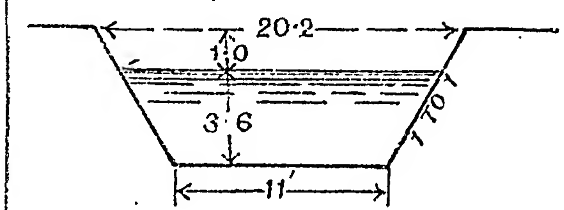
H. I. and J.	45·4	164·6	1st	Do.	296	
K. and L.	53·4	151·2	2nd	Do.	296	Bed fall = 0·15 ft. per thousand and discharge with this section and 5 ft. depth = 299·1 c.ft. per sec.
M.	56·9	130	1st	Do.	131	
N.	62·15	131	2nd	Do.	131	Bed fall = 0·15 ft. per thousand and discharge with this section and $3\frac{1}{4}$ ft. depth = 14·34 c.ft. per sec.

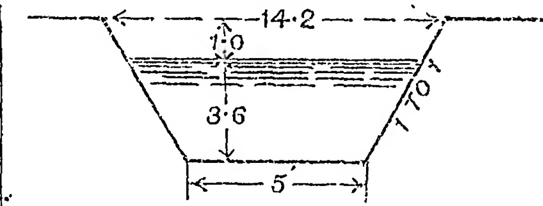
Discharge taken from Jackson's "Canal Culvert Tables." Class II (above the average).

Type Sections of Canal Distributaries.

Sections.	Gross area commanded.	Probable irrigable area commanded.	Required discharge in each section in c.ft per sec. to give a 6" watering over irrigable area in 15 days.	Distributary No.	Position along Canal line.	Bed fall per mile.	Discharge in c. ft. per second.	Type Section.
	Acres.	Acres.	C. ft. per sec.		Mile.			
A. North of Amarpura and south of Paroli Nala	602·4	300	5	1 A.	0·6	3·0	5·10	
B. Between Paroli and Madasir Nalas	1652·5	1,100	18·6	2 B. 3 B.	3 5·4	3·0 3·0	9·5 9·5	
C. Between Madasir and Sirsa Nalas	2771·1	1,300	21·8	4 C.	7	3·0	22	
D. Between Sirsa & Palasia Nalas..	6506·1	4,300	72·2	5 D. 6 D.	12 15	3·0 3·0	38 00 38·00	

E. Between Palasia and Gander Nalas	12671·1	9,500	159·6	7	E.	18	3·0	160·00	
F. Between Gander and Lachhmipura Nalas	5704·3	4,200	70·6	8	F.	24	3·0	72·00	
G. Between Lachhmipura Nala, east of Sawar and south of Khari Nadi	20261·2	10,200	171·4	9	G.	26	2½	172·00	
H. West of Khari Nadi and south of Sankria Ramthala Nala ...	9156·9	4,500	75·6	1	H.	30	3·0	76·00	
I. Between Sankria & Para Nalas	2935·6	1,600	32	11	I.	38	3·0	32·00	

Sections.	Gross area commanded.	Probable irrigable area commanded.	Required discharge in each Section in c.ft. per second to give a 6" watering over irrigable area in 15 days.	Distributary No.	Position along Canal line.	Bed fall per mile.	Discharge in c.ft. per second.	Type Section.
	Acres.	Acres.	C. ft. per sec.		Mile.			
J. Between Para Ramthala and Hernio Nalas	5189·3	3,400	57	12 J. 13 J.	41 44	3·0 3·0	29·00 29·00	
K. Between Hernio and Barla Nalas	2868·6	1,500	25·2	14 K. 15 K.	47·6 49·4	3·0 3·0	13·00 13·00	
L. Between Khari Nadi and Barla and Thaola Nalas	11371	7,500	126	16 L.	51·6	3·0	126·00	
M. Between Thaola and Nasirda Nalas	11639·6	7,700	130	17 M.	56	3·0	131·00	

N. Between Nasirda Nala and Dain Nadi	11712	7,800	131	18 N. 19 N.	58·2 59·8	3·0 0·4	66·00 66·00	
	105041·7 = 164·1 sq. miles.	64,900 = 101 sq. miles.	1,096 c.ft. per second.					*Note*—(*a*) One mile = 5,000 feet. (*b*) Discharge taken from Jackson's "Canal Culvert Tables," Class III (in good average order).

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Canal Distributaries.—Number of Falls required.

Distributary No.	Length in miles.	R. L. of ground at starting point.	R. L. of ground at end.	Total fall of country.	Proposed slope per mile in ft.	Number of Falls required.	Remarks.
1	1·3	559·00	538·34	20·66	3	No. 8 of 2 feet.	
2	1·7	555·00	528·79	26·21	3	,, 9 of 2 ,, ,, 1 of 3 ,,	
3	1·3	551·80	523·22	28·58	3	,, 8 of 3 ,,	
4	1·5	555·50	502·50	53·00	3	,, 12 of 4 ,,	
5	3·0	546·16	478·64	67·52	3	,, 14 of 4 ,,	
6	2·5	543·00	503·38	39·62	3	,, 8 of 4 ,,	
7	8·25	540 62	470·00	70·62	3	,, 11 of 4 ,, ,, 1 of 2 ,,	
8	5·25	533·20	468·34	64·86	3	,, 12 of 4 ,, ,, 1 of 1 ,,	
9	11·7	521·80	488·00	33·80	$2\frac{1}{2}$	,, 2 falls of $2\frac{1}{4}$ feet.	
10	10·9	528·50	462·00	66·50	3	,, 8 of 4 ,, ,, 1 of $1\frac{3}{4}$,,	
11	3·0	521·80	488 00	33·80	3	,, 10 of $2\frac{1}{2}$,,	
12	4·4	518·00	480·00	38·00	3	,, 10 of $2\frac{1}{2}$,,	
13	3·7	515 00	470·32	44·68	3	,, 13 of $2\frac{1}{2}$,, ,, 1 of 1 ,,	
14	1·7	512·67	480·00	32·67	3	,, 11 of $2\frac{1}{2}$,,	
15	2·7	511·66	453·50	58·16	3	,, 20 of $2\frac{1}{2}$,,	
16	4·2	514·50	416·00	98·50	3	,, 13 of 5 ,,	
17	6·8	505·90	440·00	65·90	3	,, 13 of $3\frac{1}{2}$,,	
18	3·5	502·66	455·00	47·66	3	,, 11 of 3 ,, ,, 1 of 4 ,,	
19	3·1	501·67	455·00	46·67	3	,, 11 of 3 ,, ,, 1 of 4 ,,	

APPENDIX I.

List of Nullahs, Road, etc., crossed by the main Canal from its head to Mile 62.

No.	Name.	Where crossed.	Distance in miles & ft. (approximate.)		Width of Nullah, etc., (approximate.)	R. L. of bed (approximate.)	R. L. of Canal Bed.	Level of Canal Bed.		Remarks.
								Above.	Below.	
			Mile.	Ft.	Ft.			Ft.	Ft.	
1	Paroli Nullah	Mile 1 & 2	1	2,896	140	533·00	548·32	15·32	...	Aqueduct.
2	Madasir ,, ...	,, 6 & 7	6	764	50	540·00	543·85	3·85	..	Inlet Escape.
3	Sirsa ,, ...	,, 9 & 10	9	1,630	40	536·00	540·67	4·67	...	,,
4	,, (Tributary) ...	,, 10 & 11	10	1,780	40	528·50	539 64	11·14	...	Aqueduct.
5	Palasia Nullah	,, 16 & 17	16	3,630	110	511·50	533·28	21·78	...	,,
6	Dighana ,, ...	,, 17 & 18	17	1,300	70	518·50	532·74	14·24	...	,,
7	Gauder ,, ...	,, 21 & 22	21	1,600	10	535·00	528·68	..	6·32	Inlet and Escape.
8	Sankria ,, ...	,, 34 & 35	34	3,615	45	520·00	516·96	...	3·04	,,
9	Bhirai ,, ...	,, 36 & 37	36	730	200	510·00	515·89	5·89	...	Aqueduct.
10	Para ,, ...	,, 39 & 40	39	4,500	80	507·00	513·08	6·08	...	,,
11	Nasirabad-Deoli Road ...	,, 44	44		30	508·00	510	2	...	Over bridge.
12	Hernio Nullah (main) ...	,, 45 & 46	45	2,200	150	497·00	508·92	11·92	...	Aqueduct.
13	,, (branch) ...	,, 46 & 47	46	1,130	..	505·00	508·34	3·34	...	Inlet and Escape.
14	,, ,, ...	,, 46 & 47	46	3,200	...	511·00	508·02	...	2·98	,,
15	Bijwar Nullah	,, 48 & 49	48	2,730	60	505·00	506·60	1·60	...	,,
16	Thaola ,, ...	,, 53 & 54	53	2,100	120	493·53	503·04	9·51	...	Aqueduct.
17	Manpura ,, ...	,, 55 & 56	55	400	70	495·17	502·21	7·04	...	,,
18	Nasirda ,, ...	,, 56 & 57	56	4,460	60	495·26	501·31	6·05	...	,,

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